# REPLY TO THE QUESTIONNAIRE REGARDING SCIENCE POLICY

PRESENTED TO

## THE SENATE SPECIAL COMMITTEE ON SCIENCE POLICY

BY THE

NATIONAL RESEARCH COUNCIL

OF

CANADA

FEBRUARY 1976

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THE SENATE
CANADA

OTTAWA, Ontario,
September 23, 1975.

Mr. W.G. Schneider,
President,
National Research Council of Canada,
Montreal Road,
Ottawa, Ontario.
K1A 0R6

Dear Mr. Schneider:

Re: Science Policy

The Senate Special Committee on Science Policy presented a report to the Senate on July 10, 1975. As you will see in the copy of that document which I have attached herewith, the Committee has received a new broad mandate; the Committee is "authorized to consider and report on Canadian government and other expenditures on scientific activities and matters related thereto".

Although these terms of reference could cover almost anything pertaining to science policy, our report makes it clear that we are not intending to start a general enquiry as we did in 1968. It mentions three specific areas on which we would like to concentrate.

The first item is related to futures studies or research. You will soon receive a separate letter, accompanied by a special questionnaire, regarding your views and activities in this area.

The two other items indicate our intention to revisit the scene of science policy in the light of the proposals that were put forward in Volumes 2 and 3 published in 1972 and 1973.

Your organization, if it existed in 1968, responded to our questionnaire which is reproduced in Annex B of Volume 1 of our report on science policy. Whether or not your department or agency existed in 1968, we would like you to answer that questionnaire and thus provide us with current information regarding your scientific activities.

In your response, you should take the following guidelines into account. The information requested is numerical or verbal and descriptive. For those questions requiring numerical data, we would prefer to get the actual figures, but if they are not readily available in your files, please give the best estimate and add any useful commentary.

With regard to the sections of the questionnaire requiring only a verbal descriptive response, we assume that this will not present a problem. What the Committee wishes to suggest as an overall guideline is that you concentrate on that part of the response which illustrates the existing process of science policy making and its implementation; the Committee will welcome your comments or judgements concerning future changes you believe would improve that process.

In addition, the Committee would like to receive from you a response not only to the specific recommendations, but also to the more general suggestions contained in Volumes 2 and 3 of its report on science policy and related directly or indirectly to your organization. In your reply, we expect that you will indicate the proposals that you have rejected and your reasons for this rejection. You should also identify those which have been accepted and describe how they have been implemented.

Finally, you should feel completely free to add any other advice, perception or information that may be useful to us. We would like to know the main trends which have appeared in the last few years regarding government involvement in science, technology and innovation; what are the most important developments that can be anticipated in the near future in this vital area; and how that government involvement can be made more effective to meet the needs of Canadians.

.../3

The Committee would like to receive your brief as soon as possible, but not later than the end of December. However, we do not intend to hear all government departments and agencies and I will communicate with you again later on to let you know if and when your organization will be invited to appear.

Our only purpose in undertaking this new enquiry is to help improve the formulation and implementation of Canadian science policy. For this reason, we hope that we will get your full cooperation.

Yours sincerely,

Maurice Lamontagne

Maurice Lamontagne

THE SENATE
CANADA

17 November 1975

Dr. W.G. Schneider
President
National Research Council
of Canada
Montreal Road
Ottawa, Ontario
K1A 0R6

Dear Dr. Schneider,

Re: Information for Senate Special Committee on Science Policy

In my letter to you of September 23, 1975, I informed you about the new mandate given the Senate Special Committee on Science Policy. Among other things, the letter requested, in effect, that departments and agencies responding to the Committee's questionnaire in 1968, update the information contained therein; departments or agencies which did not exist in 1968, were asked to supply information requested in this questionnaire.

In writing the letter I could foresee that certain departments and agencies - especially the larger ones - might have difficulties in supplying the numerical data called for in the questionnaire within the stated deadline. As the Committee does not wish problems of this kind to deflect attention away from its main points of concern (as stated in the July 10 report), I put the following paragraph in my letter:

> "In your response, you should take the following guidelines into account. The information requested is numerical or verbal and descriptive. For those questions requiring numerical data, we would prefer to get the actual figures, but if they are not readily available in your files, please give the best estimate and add any useful commentary."

The above foresight proved to be prophetic because Dr. Maurice LeClair and Mr. D.B. Dewar told me that some departments were concerned about supplying information called for in sections 2.5 and 2.6 of the questionnaire. Difficulties as expressed by the

representatives from MOSST were related to the deadline and to the amount of work involved considering today's restricted resources.

This representation was followed by a meeting called by Mr. Dewar at which I was able to hear the view of departmental representatives (i.e., Dr. J.D. Keys from NRC; Dr. Y.O. Fortier from Energy, Mines and Resources; and Dr. M.L. Webb from Health and Welfare). At this meeting two agreements were reached.

Firstly, Mr. Dewar stated that MOSST could supply personnel and expenditure data in response to sections 2.5 and 2.6 on behalf of departments and agencies. Although these data would not be those specifically called for by the questionnaire, I agreed that the Committee would accept MOSST's data in cases where departments and agencies could not readily supply them from their own files in the form requested and that I hoped that the Committee would feel free to ask for supplementary information if it so wished.

Secondly, in response to section 2.9 of the questionnaire, concerning projects, it was stated that some departments and agencies already have lists of projects and programs printed for other purposes. It was agreed that departments and agencies with such lists should submit them as soon as possible to the Committee instead of preparing a direct response to section 2.9. Once again, it was hoped that these lists would give satisfactory information to the Committee and thus save precious resources of departments and agencies.

I hope that the difficulties and discussions regarding the supply of information will not cause us to lose sight of our common overall objective which is to help ensure that federal government expenditures in support of scientific activities improve the manner in which the individual and collective needs of Canadians are met.

Yours sincerely,

Maurice Lamontagne

Maurice Lamontagne.

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## THE QUESTIONNAIRE

(A Science Policy for Canada, Volume 1, Annex B, 1970)

II. 1. *Introduction*

All departments, boards, crown corporations and other organizations (hereafter referred to as agencies) under the jurisdiction of the Federal Government are asked to submit briefs if they expend funds for scientific activities. Appendix B defines "scientific activities" and other terms.

II. 2. *Content of Submissions*

Briefs should contain any information, comments or counsel considered relevant to the inquiry of the Committee in view of the Committee's Order of Reference (attached as Appendix A). As well, the Committee requests information regarding the following:

2. 1. *Organization*—Supply text or diagrams regarding the following:

(a) Organizational block diagram of agency showing main units such as divisions and sections. Indicate those units conducting or funding scientific activities.

(b) Block diagram, when appropriate or necessary, indicating Parliamentary reporting channel (s), formal connections to other Federal agencies, advisory committees, etc.

(c) Block diagram indicating the organization of units (e.g. divisions, sections, task forces, etc.) responsible for scientific activities.

(d) Description of formal agreements regarding scientific activities between agency (or one of its units) with organizations outside of Canada including foreign governments or their agencies.

(e) Information concerning overseas offices of agency dealing with scientific affairs.

2. 2. *Organizational functions*

(a) What are the agency's statutory functions and powers regarding scientific activities.

(b) What organizational policies have evolved (e.g. regarding the implementation of (a)) that could be considered to define your agency's "policy regarding science" or "science policy".

(c) Taking (a) and (b) into account, briefly describe the organization's functions and responsibilities in relation to:

(i) other Federal agencies

(ii) industry

(iii) educational institutions

(iv) international representation and the monitoring of scientific activities outside of Canada

(v) other

and describe the process whereby these are achieved or honoured, citing cases-in-point if appropriate or necessary.

(d) Describe the process whereby your operational effectiveness, duties and goals are reviewed and revised.

(e) Describe any outside studies commissioned (during the last five years) to suggest improvements of agency's operating procedures.

(f) Comment on the relationship between the agency's responsibilities and powers, and its activities and programmes.

(g) What have been, what are currently, and what do you foresee as being the major hindrances to the effective performance of your functions, the honouring of your responsibilities and powers.

(h) What major changes in organization functions are forecast as probable or desirable during the next five years.

2. 3. *Personnel Policies*

(a) What steps are taken to identify and hire those members of university graduating classes who will be the most effective researchers for your organization.

(b) Have any unique criteria been developed (or any research initiated to develop criteria) to help identify those who will be creative and effective researchers.

(c) What steps are taken to identify those members of the staff with high potentiality as research administrators.

(d) What distinctions are made between administrators of research and researchers as such; for example, regarding promotion, salaries, etc.

(e) What is the policy regarding intramural and extramural education for staff members conducting or administering research.

2. 4. *Distribution of activities*

Some agencies expend funds on scientific activities in many regions of Canada. These are requested to give information and advice regarding the following:

(a) The regional pattern of agency's spending (intramural and extramural) on scientific activities (e.g. by province).

(b) The regions, if any, particularly suited for certain scientific activities.

(c) Activities carried out, on an annual basis during the last five years, to assist in the investigation of regional problems of phenomena.

(d) The role of your agency in contributing to regional development.

(e) In your experience, the cost and benefits of regional distribution of your scientific activities and the necessary conditions for this distribution to contribute to regional development.

2.5. *Personnel associated with scientific activities*

Note that the following information is required for each of the units conducting scientific activities mentioned in Section 2.1. (c).

(a) Current personnel establishment and people on strength by category of personnel. (Indicate the number of guest workers, staff-on-loan, post-doctorate fellows, etc.)

(b) Number of above professional staff devoting most of their time to administrative duties.

(c) Tabulated information regarding professional staff associated with scientific activities (divided into three categories according to degree level—i.e. bachelor, master, doctorate).

  (i) Country of birth.

  (ii) Country in which secondary education taken.

  (iii) Country in which university degree taken (bachelor, master, doctorate).

  (iv) Number of working years since graduation and number of years employed in present organization.

  (v) Average age.

  (vi) Percentage able to operate effectively in Canada's two official languages.

(d) Total number of professional staff in each degree category for each of the years 1962 to 1968 inclusive and estimates for each of the years 1969 to 1973.

(e) Percentage of turnover of professional staff in the three degree categories for each of the years 1962 to 1967.

(f) Percentage of current professional personnel who, since graduation, (i) have been employed by industry at one time, (ii) have been on the staff of universities, (iii) provincial departments or agencies, or (iv) other Federal agencies.

(g) Number of staff in each degree category on education leave.

(h) Number of university students given summer employment in the field of scientific activities for the years 1962 to 1967.

2.6. *Expenditures associated with scientific activities*

Where appropriate, please use definitions given in Appendix B.

(a) Total funds spent by agency on scientific activities broken down into the following categories:

*Functions:* (1) intramural R&D, (2) data collection, (3) scientific information, (4) testing and standardization, (5) support of R&D in industry, (6) support of R&D in universities, (7) support of higher education in engineering and science. Give Primary function (if applicable).

*Scientific discipline:* (1) engineering and technology, (2) natural sciences: (a) agricultural sciences, (b) astronomy, (c) atmospheric sciences, (d) biological sciences, (e) chemistry, (f) mathematics, (g) medical sciences, (h) oceanography, (i) physics, (j) solid earth sciences, (3) social sciences: (a) anthropology, (b) demography, (c) economics, (d) political science, (e) psychology, (f) sociology. Give primary, secondary and tertiary discipline (if applicable).

*Areas of application:* (1) nuclear energy, (2) space travel and communications, (3) war and defence, (4) agriculture (inc. fisheries and forestry), (5) construction, (6) transportation, (7) telecommunications, (8) health, (9) industry, (10) underdeveloped areas, (11) economic and fiscal policy (national and international), (12) regional development, (13) social welfare and social policy, (14) educational techniques and policies, (15) administration, (16) other (please identify). Give primary and secondary areas if applicable.

Above to be tabulated for each of the fiscal years 1962-1963 to 1966-1967, estimates for 1968-1969, and projections for the five fiscal years beginning 1969-1970.

(b) Operating and capital funds expended by the units described in (2.1 c.) (e.g. divisions, sections, etc.) for the fiscal years 1962-1963 to 1966-1967 inclusive, estimates for 1967-1968, and five year forecasts for fiscal years 1969-1970 to 1973-1974.

(c) Funds expended to further professional university education of staff for each of the fiscal years from '62-'63 to '68-'69 inclusive (e.g. costs of educational leave to take higher degree, payments to cover costs of taking courses at local universities).

2.7. *Research Policies*

In the following, the term "project" is used very broadly to describe a distinguishable discrete research activity; this could range from scientific research orientated to extend the range of understanding of one item within a particular discipline to an interdisciplinary research and development task. The term "programme" is used to denote a planned goal-directed scientific activity

requiring more than one "project" for its accomplishment. In other words, it is through a series of related "projects" that a "programme" is conducted.

(a) *Units concerned with intramural research activities*

1. Describe process whereby various types of programmes and projects are selected, initiated and monitored (e.g. what role do other Federal agencies or units play in this process).

2. How are priorities established between programmes and projects and in what terms are priorities expressed and implemented.

3. Are network methods such as Critical Path Network or Programme Evaluation and Review Technique (CPN or PERT) used to plan and monitor programmes and projects; briefly list current examples of such use.

4. What uses have been made during the last five years (and are being made currently) of contracting out projects in support of intramural programmes. In what sectors have these contracts been let (cite cases-in-point).

5. What are the policies regarding the funding of extramural research programmes in the universities and industry. How are they related to the policies governing intramural programmes and to other Federal agencies.

6. In a changing technical environment it become necessary at times to shift research resources from one programme (possibly even terminating it) to a new programme. By what process is this done and describe any current difficulties.

7. How are intramural and contracted extramural research results *transferred* to those having potential need of them (e.g. industry, other government agencies or universities).

(b) *Units exclusively concerned with extramural research activities*

Some units' sole activity in the field of the Committee's concern is the funding of extramural scientific activities.

1. Describe process whereby various types of programmes and projects are accepted for funding and describe what relation these factors have on the acceptance process:

(i) Previous record of achievement of unit or individual requesting funds

(ii) Nature of proposed project

(iii) Policies of granting agency

2. How are priorities established between programmes or projects.

3. How are projects monitored and the results evaluated.

4. How are priorities implemented in the allocation of resources to programmes or projects.

5. Are network methods such as CPN or PERT used to plan and monitor programmes or projects; briefly list current examples of such use.

6. In a changing technical environment it becomes necessary at times to shift research resources from one programme (possibly even terminating it) to a new programme. By what process is this done and describe any current difficulties.

7. How are extramural research results *transferred* to those having potential need of them.

8. What percentage of funds *available* to the agency for the support of extramural scientific activities were actually expended during each of the fiscal years '62-'63 to '66-'67.

9. What percentage of the total funds *requested* from the agency were in fact *granted* in each of the fiscal years '62-'63 to '66-'67.

2. 8. *Research Output*

The previous items have been concerned with "inputs" to research activities and the state and manner of organization of the research process. The following items refer to the research "output" and it is understood that such measures have limitations. Please give brief details regarding the following for each of the years 1962 to 1967 inclusive:

1. Patents arising from research activities. Number of licences granted and value of resulting production in Canada and elsewhere.
2. Books or journal articles arising from research activities.
3. Reports issued from agency and units.
4. Conferences or other means used to transfer information regarding the results of a project or programme to extramural groups.
5. That means for the transfer of scientific and technological data obtained from countries outside Canada, to extramural groups.
6. Individuals who had the opportunity to train themselves in specialized fields whilst employed with you and subsequently left and made important contributions to their field.
7. Research teams that have arisen in this period and who have unique and valued abilities in important fields.
8. Unique or valuable research tools, facilities, or processes added or developed during the above period.
9. Details concerning the impact of your scientific activities and research output on the advancement of scientific knowledge and Canadian economic development.
10. Any other measures or indications of research output.

2. 9. *Projects*

1. For each unit responsible for scientific activities, (intramural or extramural), list the titles or other brief descriptions of projects which were conducted

during each of the years from 1962 to 1967 inclusive. Indicate projects that are part of an overall programme and briefly describe the programme.

2. Present case histories of what you consider as the most significant completed projects of the last five years. These should be selected as examples of what are considered to be the results of the agency when operating in its role with maximum effectiveness; in other words, examples of what the agency considers among its "best work". The projects selected, when possible, should be presented under the broad categories of "basic research", "applied research", and "development", and it is suggested that no more than *five* are to be singled out in any one category.

2. 10. *Organizations not currently engaged in scientific activities*

The Special Committee on Science Policy was constituted to consider and report upon those agencies of the Federal Government directly engaged in scientific activities. The Committee was also charged with recommending a science policy for Canada and is of the opinion that any government policy related to science must take some account of the effects of science on all governmental functions including those of agencies or units not engaged in scientific activities. The Committee, therefore, invites all agencies under the jurisdiction of the Federal Government to include in their briefs comments as to the effects of scientific activities on their own operations and in particular, to comment on the following items:

1. Forecasts of the effects of changes in *technology* on the agency's operations, functions and responsibilities during the next 5 to 10 years.

2. Studies of possible improvements in the agency's effectiveness due to new scientific or technical developments.

3. The type of scientific or technical advice sought during the last five years; the source of this advice.

4. Future plans determined by, or deternated to take account of, recent scientific and technical developments.

## III ANSWER TO THE QUESTIONNAIRE

## I N D E X

# LIST OF EXHIBITS

## 2.1 *Organization*

### 2.1(a),(b), and (c) Organizational Units and Advisory Committees

The National Research Council of Canada consists of the President, the Vice-Presidents, and up to 17 other members appointed by the Governor in Council. The Council is a body corporate and is required to meet at least three times a year in the city of Ottawa.

The Council reports to Parliament through a designated minister, Mr. C.M. Drury, Minister of State for Science and Technology and Minister of Public Works. Except for the permanent officers, Council members are appointed for a term of three years and serve without salary. Council members are drawn from the senior representatives of universities and industry.
A broad base of scientific disciplines and regional representation is sought in the membership of Council.

A recent executive reorganization has provided three Group Directors for NRC Laboratories, and a more functional arrangement of Vice Presidential responsibilities. Areas of responsibility are detailed in the organizational chart, Figure (a). The Management Committee is composed of the President, the Vice-Presidents, the Group Directors, and the Secretary of the Council.
The Tactical Studies Committee, composed of the three

Group Directors, is the focal point in the Laboratories for the planning and evaluation of programs and projects.

The NRC Laboratories are now organized in ten divisions - Biological Sciences, Chemistry, Physics, Herzberg Institute of Astrophysics, Building Research, Mechanical Engineering, the National Aeronautical Establishment, Electrical Engineering, the Atlantic Regional Laboratory, and the Prairie Regional Laboratory. Administrative services are organised separately to relieve the researchers from administrative duties.

A network of Associate Committees (Figure (b)), whose members are drawn from the Canadian scientific and engineering community, provide an effective means of coordinating scientific activities across the country, as well as contributing to the exchange and dissemination of information.

The organizational units of the National Research Council are presented in Figure (c).

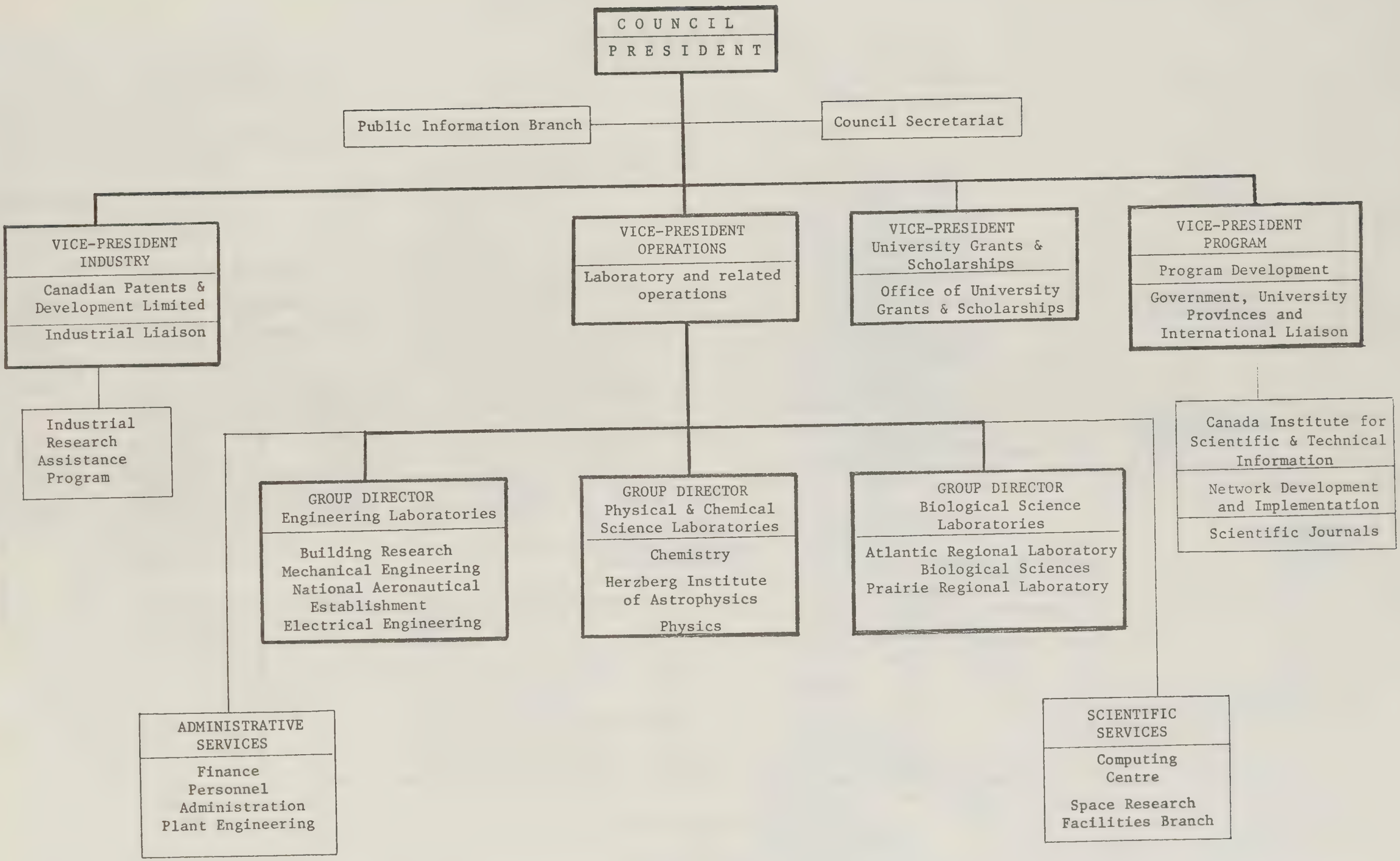



Figure (a)

ORGANIZATIONAL BLOCK DIAGRAM

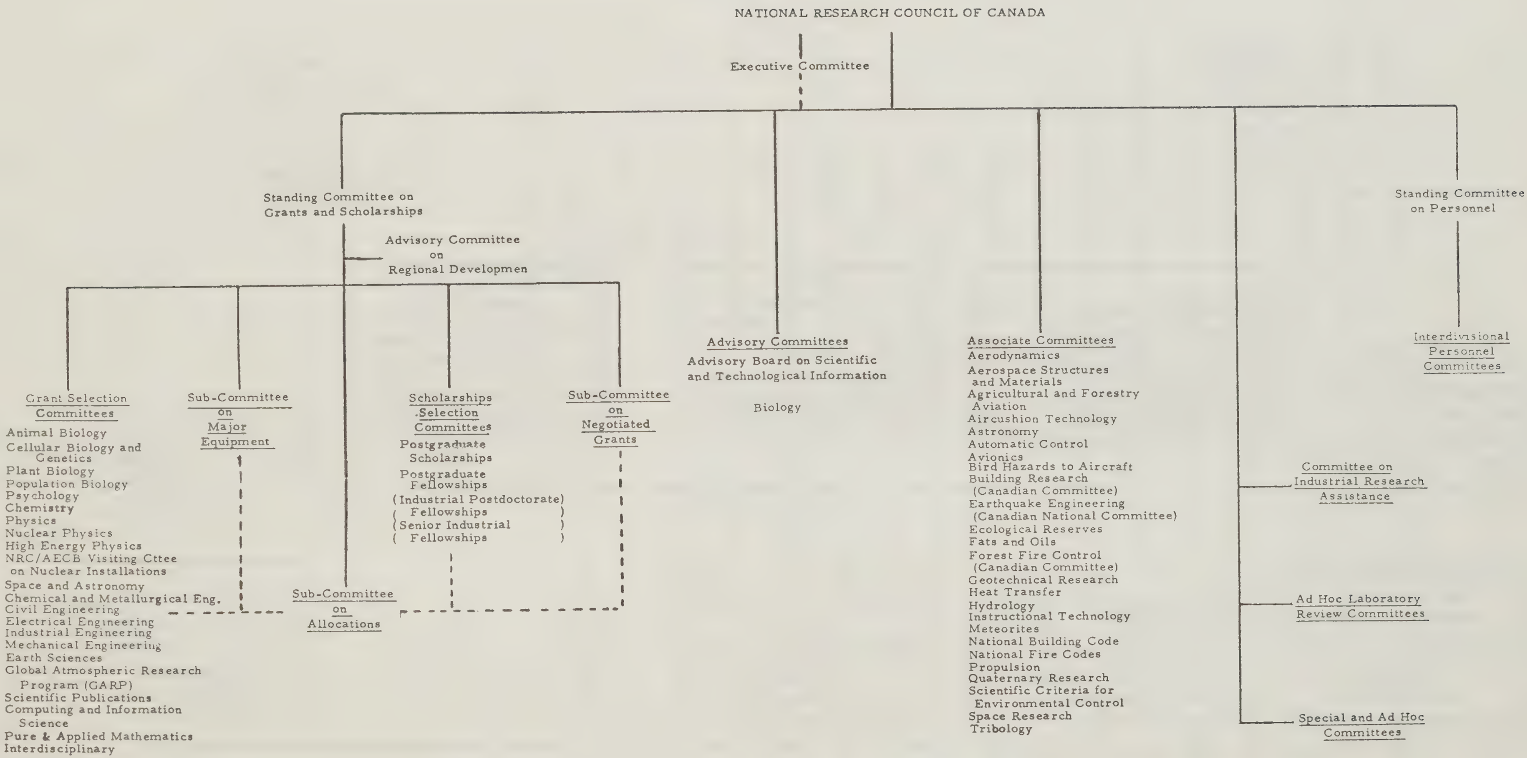



Figure (b)

ASSOCIATE COMMITTEES

Figure (c) ORGANIZATIONAL UNITS
NRC LABORATORIES

Vice-President Operations

Group Director Biological Science Laboratories | Group Director Engineering Laboratories | Group Director Physical and Chemical Science Laboratories

## Group Director Biological Science Laboratories

### ATLANTIC REGIONAL LABORATORY

Biophysics
Chemistry of Natural Products
High Temperature Chemistry
Lichenology
Marine Plants
Microbiology

### BIOLOGICAL SCIENCES

Animal and Cell Physiology
Biomathematics
Bio-organic Chemistry
Cell Biochemistry
Cell Biophysics
Ecological Kinetics
Environmental Physiology
Environmental Secretariat
Food Technology
Genetics
Immunochemistry
Membrane Biochemistry
Molecular Biophysics
Plant Cell and Bacteria Culture
Radiation Chemistry
Radiation Dosimetry
X-ray Crystallography

### PRAIRIE REGIONAL LABORATORY

Biotechnology
Microbiology
Plant Biochemistry

## Group Director Engineering Laboratories

### BUILDING RESEARCH

Building Design and Use
Building Materials
Building Services
Building Structures
Codes and Standards
Fire Research
Geotechnical Section
Information Services
Instrumentation Unit
Noise and Vibration

### MECHANICAL ENGINEERING

Analysis Laboratory
Control Systems and Human Engineering Laboratory
Engine Laboratory
Fuels and Lubricants Laboratory
Gas Dynamics Laboratory
Hydraulics Laboratory
Instrument Laboratory
Low Temperature Laboratory
Manufacturing Technology Centre
Marine Dynamics and Ship Laboratory

### NATIONAL AERONAUTICAL ESTABLISHMENT

Low Speed Aerodynamics
High Speed Aerodynamics
Unsteady Aerodynamics
Flight Research
Structures and Materials

### ELECTRICAL ENGINEERING

Computer Graphics
Electromagnetic Engineering
Electron Physics
Electronics Engineering
Information Science
Medical Engineering
Power Engineering

## Group Director Physical and Chemical Science Laboratories

### CHEMISTRY

Analytical Chemistry
Chemical Engineering
Chemical Spectroscopy
Colloid Chemistry
High Polymer Chemistry
High Pressure Chemistry
Hydrocarbon Chemistry
Kinetics, Photochemistry and Catalysis
Metallic Corrosion and Oxidation
Metallurgical Chemistry
Molecular Structures
Organic Spectrochemistry
Organic Synthesis
Textile Chemistry
Theoretical Chemistry
Thermochemistry

### HERZBERG INSTITUTE OF ASTRO-PHYSICS

Astronomy
Planetary Sciences
Space Physics
Spectroscopy
Spectroscopy of Larger Molecules
Algonquin Radio Observatory, Lake Traverse
Dominion Astrophysical Observatory, Victoria
Dominion Radio Astrophysical Observatory, Penticton

### PHYSICS

Acoustics
Electricity
Heat and Thermometry
High Energy Physics
High Temperature Physics
Laser and Plasma Physics
Mechanics
Metal Physics
Optical Physics
Optics
Photogrammetric Research
Solid State Physics
Time and Frequency
X-rays and Nuclear Radiations

Figure (c) continued

ORGANIZATIONAL UNITS

OFFICE OF GRANTS AND SCHOLARSHIPS

- VICE-PRESIDENT Grants & Schol.
  - DIRECTOR
    - ASSISTANT TO THE DIRECTOR
    - ANNUAL GRANTS
      - Operating Grants
      - Equipment Grants
      - Major Equipment Grants
      - Group Grants
      - Travel Fellowships
      - Conference Grants
      - Publication Grants
      - NRC/Nuffield Foundation Visiting Lectureships
      - E.W.R. Steacie Memorial Fellowships
      - Senior Industrial Fellowships
      - General Promotion Grants
      - General Research Grants
      - New Research Idea Grants
    - SCHOLARSHIPS
      - Postgraduate Scholarships
      - Postdoctoral Fellowships
      - 1967 Science Scholarships
      - Industrial Postdoctoral Fellowships
      - Industrial Cooperative Fellowships
      - Postgraduate Scholarships in Science Librarianship and Documentation
      - Postgraduate Fellowships in Meteorology and Atmospheric Sciences
      - NATO Science Fellowships
    - NEGOTIATED GRANTS
      - Negotiated Development Grants
      - Special Major Installation Grants
      - Institute Grants
    - PRAI GRANTS and Special Project Grants
    - PLANNING REVIEW & ANALYSIS
    - SECRETARIAT SERVICES
    - FINANCE
    - ADMINISTRATION

Figure (c) continued

ORGANIZATIONAL UNITS

OFFICE OF INDUSTRIAL RELATIONS

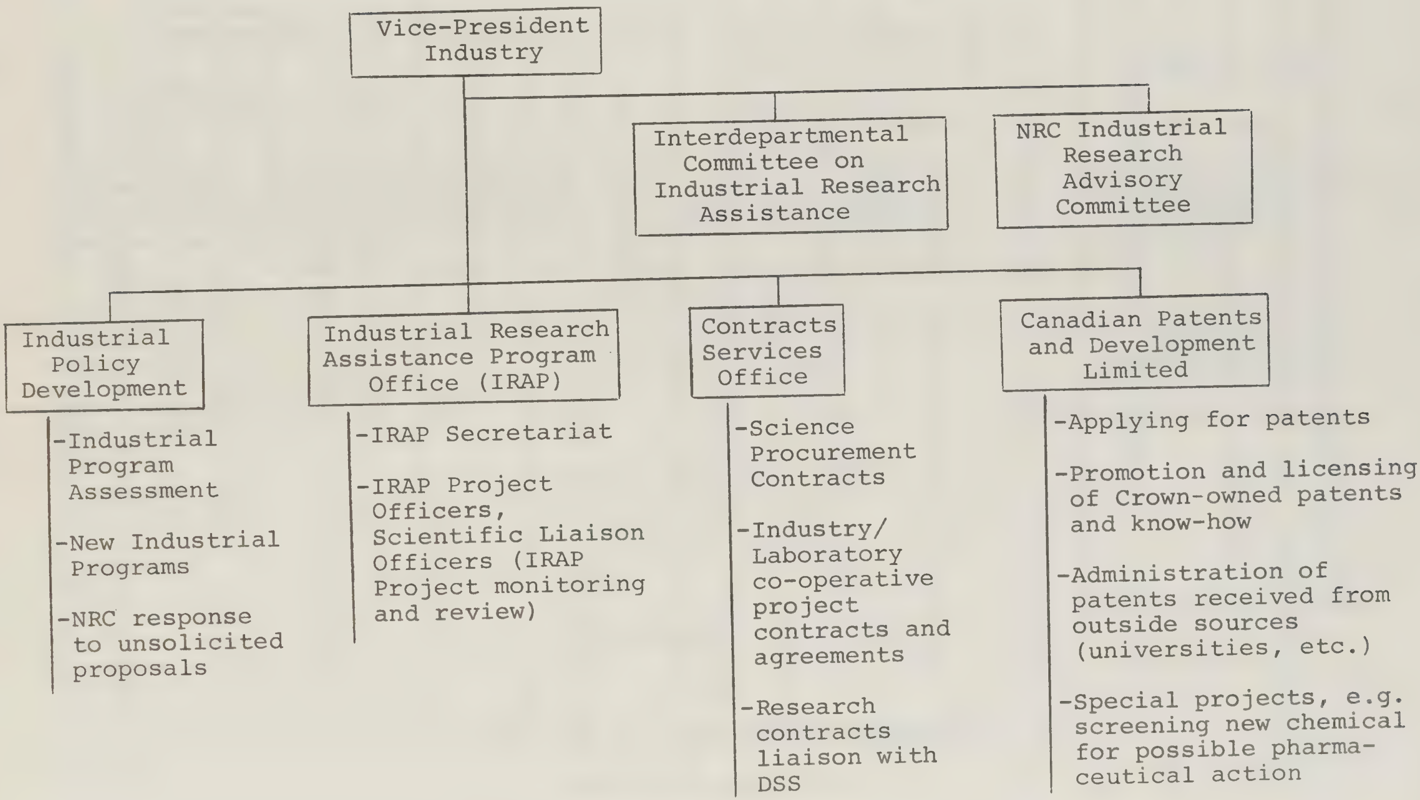


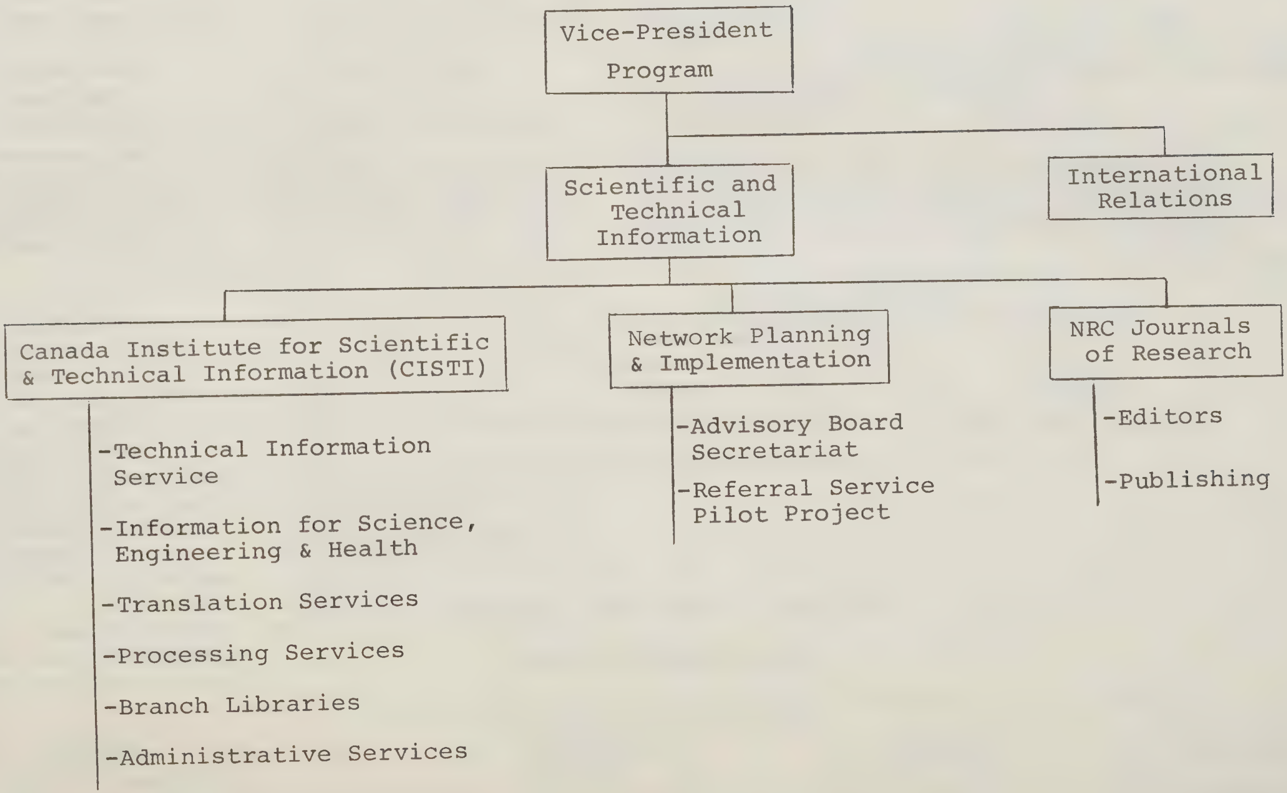
Figure (c) continued

ORGANIZATIONAL UNITS

SCIENTIFIC AND TECHNICAL INFORMATION

and

INTERNATIONAL RELATIONS



2.1(d) Formal Agreements with Foreign Organizations

The National Research Council has formal agreements for exchange of scientists and information with:

- The USSR Academy of Sciences,
- The Czechoslovak Academy of Sciences,
- The Conselho Nacional de Pesquizas of Brazil,
- Le Centre National de la Recherche Scientifique of France,
- The Japan Society for the Promotion of Science. (See also section 2.2(c) (iv).)

In addition, NRC manages a program for exchange of scientists under the Canada-France Cultural Agreement and the CIDA/NRC Research Associateship program.

The National Research Council has formal agreements for joint activities with:

- The US National Aeronautics and Space Administration regarding the Churchill Research Range, and the Remote Manipulator System,
- Le Centre National de la Recherche Scientifique of France and the University of Hawaii regarding the Canada-France-Hawaii Telescope Corporation.

The agreements noted in this section have associated Exchanges of Notes at governmental level.

The National Research Council has also entered into letter agreements with organizations in various countries

concerning specific projects, most of which have been completed. (Records are not retained in a readily accessible form because no continuing responsibility is accepted by NRC in these cases.) Examples are:

- Welcoming and assisting of eclipse expeditions,
- Loan of lunar samples and related equipment to Canadian scientists,
- Use of foreign particle accelerators by Canadian nuclear physicists,
- Use of Canadian experimental facilities (e.g. wind tunnels) by foreign scientists and, on a commercial basis, by foreign corporations.

The National Research Council is the responsible body or one of the responsible bodies, on behalf of Canada, for a number of governmental and quasi-governmental international organizations or programs including:

- The International Bureau of Weights and Measures,
- UNESCO : Man and the Biosphere
  International Hydrologic Program,
- The International Council of Scientific Unions and the World Meteorological Organization:
  The Global Atmospheric Research Program.

(See also section 2.2(c)(iv).)

The National Research Council is responsible for

adherence on behalf of Canadian scientists and engineers to many international scientific unions and similar bodies.

The National Research Council, through its Canada Institute for Scientific and Technical Information, has agreements for exchange of publications with 637 institutions in 61 countries. The NRC Journals of Research constitute the medium of exchange in most of these agreements.

2.1(e) Overseas Offices

The National Research Council has no overseas offices.

## 2.2 *Organizational Functions*

In order to implement the responsibilities assigned to it by statute, NRC operations are organized in three separate programs, each supported financially by a separate Parliamentary vote:

Program A: Natural Sciences and Engineering Research

Objective

To provide a national foundation upon which to build for the creation, application and use of knowledge derived from the natural sciences and engineering.

Sub-Objectives

To promote, assist and perform research for the creation of new knowledge derived from the natural sciences and engineering.

To apply knowledge derived from the natural sciences and engineering to the solution of problems of national concern.

To apply and use engineering and the natural sciences to assist industry in Canada with the development of new and improved processes, methods, products, systems, techniques and services.

To develop and maintain national standards and criteria based on the natural sciences and engineering.

Program Description

- Basic and Exploratory Research in the Natural Sciences and Engineering: development of engineering

fundamentals; acquisition of new engineering technologies; discovery of new applications for engineering technologies; development of scientific competence; acquisition of new scientific knowledge; discovery of new applications of science.

- Research on Long-Term Problems of National Concern: application of engineering and scientific expertise to the solution of long-term problems of national concern, such as transportation, energy, food, building, and construction.
- Research in Direct Support of Industrial Innovation and Development: performance and promotion of exploratory and applied research in selected areas for the advancement of technology required for Canadian industrial development; use of effective methods of technology transfer, financial assistance, and selected cooperative projects on processes, systems, materials, and products to strengthen the research, development, and innovative capacity of industry in Canada.
- Research to Provide Technological Support of Social objectives: application of scientific and engineering expertise in support of national objectives such as health, law, safety, environmental quality and quality of Canadian life.
- National Facilities: provision and management of

national research and development facilities as a service to industry, governments, and universities.

- Research and Services Related to Standards: research in primary physical standards and provision of services in support of national and international standards,
- Administration: administrative support including financial and personnel services for this and other programs of the Council.

Program B: Scholarships and Grants in Aid of Research

Objective

To promote and support the development and maintenance of research and the provision of highly qualified manpower in the natural sciences and engineering.

Sub-Objectives

To support excellence in research for the creation of new knowledge in the natural sciences and engineering.

To promote and support the development of research in selected fields of regional and national importance.

To assist in the provision and development of highly qualified manpower.

Program Description

- Peer-Adjudicated Grants: grants for research expenses and equipment costs awarded to selected

individuals and groups by peer adjudication.

- Developmental Grants: grants negotiated with individuals, groups, or institutions to resolve problems related to scientific, economic, and resource development.
- Training and Development of Highly Qualified Manpower: scholarships and fellowships awarded in national competitions to graduate students, postdoctorate fellows, and senior scientists and engineers in universities and Canadian industry for advanced study, research, or professional development - tenable in universities, industrial firms, and other institutions in Canada or abroad.
- National and International Activities: grants to support national and international scientific and engineering conferences and studies, the exchange of scientists and engineers, and selected activities of scientific and learned institutions.

Program C: Scientific and Technical Information

Objective

To facilitate the use of scientific and technical information by the government and people of Canada.

Sub-Objectives

To provide and maintain services associated with scientific and technical information to meet the needs

of the government and people of Canada.

To conduct research into the need for and methods of accomplishing the transfer of scientific and technical information in response to user needs.

To participate in the provision of library and information services for the government and people of Canada.

Program Description

- Information Services: operation and support of services to provide for the collection, storage, retrieval, analysis, and transfer of scientific and technical information; support for the publication of journals of research in engineering and science.
- Network Implementation: implementation and maintenance of a Canadian network of scientific and technical information services, including a referral service; the establishment of links with other national and international networks and services.
- Research and Development: research into the requirements for collection, storage, retrieval, analysis, and transfer of scientific and technical information; improvement of these and other related processes and development of new processes to meet

the demonstrable needs of the users; development of standards, procedures, and processes for intersystem exchanges of scientific and technical information through participation and agreement with other national and international organizations.

2.2(a) Statutory Functions and Powers

NRC's statutory functions and powers are described in the National Research Council Act, R.S., C.N-14, amended by R.S., C.14 (2nd Supp.), 1973. The second supplement of the Revised Statutes of Canada adds to the powers of Council by authorizing it "to operate and administer any astronomical observatories established or maintained by the Government of Canada."

2.2(b) Organizational Policies

The National Research Council concentrates on those responsibilities explicitly assigned to it by statute, and includes those activities that are deemed highly important from a national standpoint, but which, for various reasons, cannot be done by other agencies.

The following specific policies relate to the above-mentioned role:

- In order to remain in the forefront of scientific and engineering research, NRC performs basic and exploratory research for the creation and application of new knowledge. The level of this effort

constitutes between one-quarter and one-third of NRC operations.

- NRC places emphasis on research in promising areas of advanced technology and on research related to long-term problems of national concern, such as energy, food, building and construction, and transportation.
- NRC's industrial research and development role complements and reinforces R&D in Canadian industry by the development and transfer of technology and by direct assistance to R&D projects in industry.
- Within its competence, NRC provides research support toward social objectives such as public safety and security, protection of property, health, and environmental quality.
- NRC establishes and manages major scientific and technical facilities that serve a variety of users.
- NRC provides a national reference centre for standards of measurement and performance.

Because of NRC's non-regulatory nature and independence as a research agency with broad scientific expertise, it is frequently called upon for consultation or to undertake investigations on specific matters. In some cases this amounts to what could be described as a "scientific ombudsman" task. Accordingly:

- NRC recognizes an obligation to provide, within its competence, independent investigation of scientific and technical issues that are in the national interest.

2.2(c) Functions and Responsibilities

In addition to the primary role of NRC set out above, its research activities necessarily interface with, and complement, those of other government laboratories, industries and universities. The following policies define these interrealtions more explicitly:

2.2(c) (i) Relations with Other Federal Agencies

Federal government departments with no laboratories of their own or departments with specialized R&D programs frequently require assistance in areas in which NRC has expertise or facilities. In addition to providing such assistance, NRC also has a continuing responsibility to do work of importance to Canada which does not fall within existing departmental missions or which broadly encompasses a number of missions. The following specific policy statements have been adopted:

- In selected program areas, either through the NRC mandate or by specific agreement with government departments and agencies, R&D undertaken by NRC may be directly related to the program of federal departments and generally constitutes a specified

or complementary research component of an integrated federal program.

- NRC engages in cooperative research and development at the project level with researchers in individual government departments and agencies.
- Within its capabilities, NRC responds positively to requests from federal departments and agencies for service from its unique facilities.
- NRC provides scientific and engineering advice, as appropriate, in support of other federal departmental programs when the required expert knowledge resides within NRC. As an independent agency, NRC does not accept responsibility for regulatory activities of government departments and agencies.

2.2(c) (ii) Relations with Industry

Within its capabilities, NRC meets the research needs of industry in Canada through the research of its laboratories, staff consultations, information services, project grants or contracts, and other forms of assistance. NRC complements research in industry and, where feasible, it encourages and assists R&D projects in industry. A significant aspect of NRC's industrial activity takes place through the extramural industrial program, as described in section 2.7(b) (II). Emphasis is being given to a closer coupling of NRC Laboratory research and industrial R&D in selected projects. This involves

increased NRC initiatives in developing collaborative research projects with industry. Project proposals developed by NRC laboratories for collaborative work to be carried out in industry are eligible for assistance through grants or contracts.

These and other approaches are directed toward a more effective transfer of technology from NRC Laboratories to industry. Specifically:

- NRC has developed from existing resources, including the Industrial Research Assistance Program and NRC Laboratories, a program specifically directed to enhancing applied research and technological development, and its transfer into industry. This involves the formation of joint NRC/industry teams to work on selected projects which may be initiated by either industry or NRC. In either case, the funding is subject to negotiated agreement.
- NRC work on a proposed industrial technology is pursued to a point where a competent company or group of companies can see its value and is prepared to take over final development and application. Bringing a company or companies to this point usually requires that they participate in the research at an early stage. Assignment to a

company depends upon the company's overall capability and on its plans regarding exploitation.

- NRC encourages and assists in the creation and strengthening of R&D teams in industry, through the introduction of new staff and exchanges between industry, the universities, and the NRC Laboratories.
- NRC provides scientific and engineering advice and assistance in solving technological problems in support of Canadian industry when the appropriate expertise is available at NRC.

2.2(c) (iii) Relations with Universities

A major part of the NRC role in respect of universities is carried out through the extramural program of Scholarships and Grants in Aid of Research as described in section 2.7(b)(I). To maximize the utilization of the scientific and engineering research capability in Canadian universities which NRC has fostered over the years, it is desirable that strong interactions be maintained between NRC, industry, and universities:

- In fields of research where NRC has identified the possibility of significant advances in fundamental techniques, maximum collaboration is sought from university researchers.
- NRC participates in cooperative and collaborative research programs with Canadian universities,

through agreements or contracts, when the results of such research are considered to be a contribution to national research and development programs in which NRC has a defined responsibility.

- NRC continues to encourage the interchange of scientific and engineering personnel between NRC and university laboratories.

2.2(c) (iv) International Representation

NRC acts as a focal point for Canadian international scientific and engineering affiliations, being the responsible body for 12 of the 17 member unions of the International Council of Scientific Unions (ICSU), to which Canada adheres. In addition, Canada, through NRC, adheres to several special and scientific committees of ICSU and to independent scientific associates of ICSU, such as the Pacific Science Association. NRC is also responsible for Canadian adherence to some 10 similar bodies such as the International Society of Soil Mechanics and Foundation Engineering. It cooperates with the Engineering Institute of Canada in regard to the World Federation of Engineering Organizations and the Pan American Federation of Engineering Societies.

Canada has intergovernmental agreements for cooperation in scientific and technological matters with the U.S.S.R., Belgium, and Germany, and, less formally,

with France and Japan. It also participates in scientific and technological activities of multilateral intergovernmental organizations such as UNESCO, OECD, NATO, and the International Energy Agency. NRC, in consultation with the Department of External Affairs and other departments and agencies acts as the Canadian representative for these bilateral and multilateral activities on matters pertaining to NRC's responsibilities. Occasionally, as in the case of UNESCO's Man and the Biosphere program and the Global Atmospheric Research Program of the ICSU and the World Meteorological Organization, it has been necessary to set up Canadian national committees to involve a wider portion of the scientific community. Alternatively, an existing NRC Associate Committee can be used; for example, the Associate Committee on Hydrology represents Canada in UNESCO's International Hydrologic Program.

NRC has exchange agreements with the Academy of Sciences of the U.S.S.R., the Centre National de la Recherche Scientifique of France, the Academy of Sciences of Czechoslovakia, and the Japan Society for the Promotion of Science. It manages the scientific part of the General Exchanges Agreements with France (intergovernmental) and, using funds provided by CIDA, manages an exchange agreement between NRC and the Conselho Nacional de Pesquizas of Brazil.

2.2(c) (v) Relations with Provincial Research Institutes

Since a number of provincial research councils and foundations have objectives somewhat similar to NRC's national role, NRC's activities are, where possible, related to those of provincial institutions in a series mode rather than in parallel.

It is considered desirable to have engineering and scientific R&D resources accessible to the need for such resources. It is therefore NRC policy to regard provincial institutions as having prior responsibility for the satisfaction of provincial needs within their capability. NRC responds to requests that cannot be thus satisfied.

NRC is prepared to engage more actively in cooperative R&D with provincial agencies when the unique capabilities of both can be jointly employed to further a national R&D purpose. Cases in point:

- Participation in the development of a federal energy R&D program.
- Collaborative development of a food R&D program.
- Participation with an industrial consortium in the provision of a Remote Manipulator System for the NASA space shuttle program.
- A pilot project to assist in evolution of joint industry/laboratory programs.
- A pilot project to assist in evolution of joint university/laboratory programs.

- Collaboration with university and government scientists in astronomy and space research.
- Collaboration with provincial non-profit research organizations in the provision of technical information to small and medium manufacturing industries.

2.2(d) Process of Review

The President of the National Research Council reports to Parliament through a minister, in contrast to the deputy minister of a government department who reports to the minister. The regular review by Council of the duties, goals, and work of the agency provides the mechanism by which Parliament can be assured that the directions followed are in keeping with national purposes. The methods used by Council to plan and monitor projects are described in the answer to question 2.7. This mode of operation ensures that due consideration is given both to short-term needs and long-term benefits.

The NRC Management Committee carries out strategic and tactical studies for consideration and concurrence by Council. By delegation from the President, the members of this Committee assume responsibility, authority, and accountability for specific activities within the total NRC program.

Council itself carries out a continuing review of programs and program priorities. This process takes place through ad hoc Council review committees that

examine the program goals, activities, achievements, and proposed future directions. The results of such an examination are measured against NRC policies and objectives, and conclusions are presented for Council's consideration and recommendation.

In addition, NRC is subject to scrutiny by the Treasury Board, cabinet committees, and parliamentary committees such as the Miscellaneous Estimates Committee, as well as the office of the Auditor General.

2.2(e) Outside Studies

This function is fulfilled by the duly appointed members of Council.

2.2(f) Responsibilities, Powers, Programs

In response to the powers assigned to the Council under its Act "to undertake, assist, or promote scientific and industrial research," NRC has developed a capable and productive laboratory program, a shared-cost program to develop research capability in industry, and a grants and scholarships program to foster research in universities. These programs have not remained static; changes have occurred and are occurring that respond to changing Canadian priorities in respect of laboratory research programs, support for university research, pilot programs to link research activities in government, university, and industry, and a scientific and technical information program that serves all sectors.

2.2(g) <u>Hindrances</u>

The expansion of scientific and engineering activity since the war resulted in a steady increase in the number of researchers employed by NRC Laboratories, reaching approximately 600 by 1967. Since 1968, the total number of researchers has remained constant, although their average salary continued to increase as a result of contract settlements and promotions. This has resulted in a decreasing proportion of the budget of the NRC Laboratories being available for the purchase of equipment, supplies, and services. Against a background of rapidly increasing costs, the effect has been to reduce dramatically the ability of the Laboratories to purchase new equipment. Since many kinds of modern scientific instruments become obsolete in approximately 10 years, the Laboratories are in danger of losing their position in the forefront of scientific endeavour. Moreover, with limited ability to purchase new equipment, it becomes more difficult to introduce new projects or to change the direction of existing projects.

The constant number of researchers during the past seven years has also affected their average age, which reached 44 years in 1973, compared with 35 years in 1953. The average age appears to have stabilized during the past two or three years, partly because of a trend towards earlier retirement. It is widely held that the average

age of a research community should not only be stable, but also considerably lower than the present value for NRC researchers. Unless more young scientists and engineers can be recruited, it is unlikely that the average age can be reduced substantially.

The ever increasing administrative demands placed on the National Research Council, without the provision of more administrative personnel, have resulted in the diversion of research staff, particularly directors and sectional heads, from the tasks for which they are best suited. This diversion is considered to be a significant hindrance to the management of the research laboratories.

In industrial research, the development of long-term policies to guide Canada's industrial development will be of immeasurable assistance in selecting those areas of research and development that could return the maximum benefit to Canada. Such policies should allow not just for the support and fostering of industrial research and development, but should also ensure that the results of research and development can be exploited in Canada for the benefit of all Canadians.

2.2(h) Forecast Changes in Organizational Function

NRC, with its strong scientific and engineering ties throughout Canada, and with the appropriate program activities, is in a strong position to bring together in a confluence of interest, the R&D capabilities of the

three sectors (government, industry, and university) to deal with problems of ongoing national concern.

At the present time, NRC has research laboratories in Ottawa, Saskatoon, and Halifax, with smaller groups in other locations. In order that the National Research Council can fulfil its role as a national body responsive to the needs of Canadians in all parts of Canada, it is anticipated that additional laboratories will be established in other parts of Canada in the future.

## 2.3 *Personnel Policies*

The responsibility for staff appointments and promotion is assigned by the NRC Act to the National Research Council. Recommendations are generally made by the respective division and reviewed by an inter-divisional committee of laboratory directors. The recommendations of this committee are in turn considered by the Committee on Personnel, a Standing Committee of the National Research Council with responsibility for appointments and promotions.

### 2.3(a) Hiring Policies

In general, NRC researchers are recruited through the Research Associate program or by advertisement of specific Research Officer positions. However, a significant proportion of candidates are recruited through direct contacts with university departments and others in the scientific community throughout Canada and abroad.

The evaluation of candidates is based principally on the following factors:

- academic record,
- research achievement (e.g. published papers, reports, or patents),
- relevant experience,
- peer appraisal,
- personal characteristics.

Candidates for specific positions as Research Officers are required to demonstrate effective research capability in a closely related field of science or engineering. On the other hand the Research Associate program does provide more latitude for young scientists or engineers to enter fields of research somewhat different from their previous experience and in some cases of a more applied nature.

New research personnel may be appointed either as Research Associates or as Research Officers (members of staff). The Research Associate program, which came into effect on April 1, 1975, replaces the earlier program of Postdoctorate Fellowships (PDF). As with the PDF program, awards are made on the basis of demonstrated ability and promise to perform original research of high quality. Applicants must possess at least a Ph.D. degree in natural science or a Master's degree in engineering. The salaries and staff benefits offered are comparable to those currently available to members of the regular staff of NRC. The initial award is for a period of one year and may be renewed at intervals for a total period of up to five years.

Research officers are normally appointed for an initial term of five years. This is normally followed by continuing employment "during pleasure". This

arrangement provides a useful opportunity for reviewing each employee's relationship to the work of the Council. Generally all candidates considered for appointment to Research Officer positions possess either a Ph.D. degree or equivalent post-graduate experience.

2.3(b) <u>Identification of Researchers</u>

The major criterion for staff selection in NRC is excellence, but the selection process used to judge excellence is flexible and, due to the diverse nature of NRC's intramural program, is necessarily somewhat subjective. No single set of rigid requirements is likely to be uniformly applicable to the wide range of positions to be filled. Many of the appointments to Research Officer positions were made from personnel previously employed by NRC under the PDF program. In these cases the selection of staff can be based on the direct appraisal of researchers over a period of up to two years by the respective section heads and laboratory directors. Under the new Research Associate program appointments to staff can be made on the basis of direct observation of performance over a period of up to five years.

Promotion of research staff depends on achievement; this is usually measured in terms of published books,

papers, reports, and patents, national and international reputation, and participation in or recognition by appropriate professional societies. Individual researchers can advance to the most senior grade, Principal Research Officer, by research achievement alone, without necessarily becoming involved in research administration.

2.3(c) Identification of Research Administrators

For the most part the administration of NRC's intramural research program is performed by the laboratory heads (comprising Assistant Directors, Associate Directors, Directors, and Group Directors). Recommendations for the appointment of laboratory directors originate within the Management Committee, are examined by the Council's Committee on Personnel, and are approved by Council. As is the case with less senior personnel, the criteria for selection, e.g. capacity for scientific leadership, managerial ability, experience as a section head, are used with flexibility as the requirements may vary from one division to another.

It is NRC policy to provide opportunities for those younger members of the staff who possess the appropriate qualities of leadership to so develop their careers that they may eventually join the senior management. These scientists and engineers become more familiar with the work of the National Research Council by serving either

as coordinators of major projects or on task forces and interdivisional committees. Further broadening of experience and development of managerial skills is achieved by:

- participation in management courses,
- representation of NRC on interdepartmental committees,
- secondment or staff postings to other government departments, universities, or industry.

2.3(d) Distinctions between Researchers and Administrators of Research

Insofar as the term research administrator is used to describe the function of the laboratory heads, there are different salary scales and promotion procedures for research administrators and researchers. Salary scales for the Director grades are flexible and not subject to collective bargaining. Promotions are considered by senior management.

Research Officers on the other hand are paid in salary scales which are subject to collective bargaining. Their promotions are considered by interdivisional committees on the basis outlined above. In addition to its Research Officers NRC employs a total of about 100 Research Council Officers, whose duties, although scientific in outlook, cannot be considered as research. A few of these are involved in research administration.

Their salary scale is identical to that of the Research Officers, although the criteria for, and consideration of, promotion is the responsibility of a separate committee.

2.3(e) Extramural Education Policy

Educational leave may be granted to members of the professional staff who do not possess a Ph.D. and have demonstrated outstanding ability. Professional development leave may be granted to members of the professional staff who have completed formal academic training and who have established records of scientific achievement. This development leave may be granted for participation in seminars, workshops or short courses, or to enable the professional to conduct research or to perform work related to their normal research programs in other institutions.

## 2.4 *Regional Distribution of Activities*

### 2.4(a) Regional Pattern of Spending

A geographical distribution of intramural and extramural spending by the National Research Council in the fiscal year 1974-75 is presented in the following table:

| REGION | EXPENDITURES IN THOUSANDS OF DOLLARS | | |
|---|---|---|---|
| | Intramural[1] | Extramural | Total |
| Alberta | | 7,563 | 7,563 |
| British Columbia | 1,746 | 8,612 | 10,358 |
| Manitoba | 1,457 | 3,697 | 5,154 |
| New Brunswick | | 1,425 | 1,425 |
| Newfoundland | 1 | 1,092 | 1,093 |
| Nova Scotia | 2,073 | 2,461 | 4,534 |
| Ontario (excluding the National Capital Region) | 741 | 37,091 | 103,629 |
| Ontario (National Capital Region) | 65,797 | | |
| Prince Edward Island | | 102 | 102 |
| Quebec | 258 | 17,926 | 18,184 |
| Saskatchewan | 2,789 | 2,247 | 5,036 |
| Other in Canada[2] | | 2,283 | 2,283 |
| Total in Canada | 74,862 | 84,499 | 159,361 |
| Foreign | | 4,103 | 4,103 |
| TOTAL | 74,862 | 88,602 | 163,464 |

[1] Includes financial encumbrances from other government departments.

[2] The sum presented under this title is for some of the smaller grants administered by the Office of Grants and Scholarships which cannot readily be presented by province.

2.4(b) Regions Particularly Suited for Certain Scientific Activities

Certain activities of the NRC Laboratories are carried out in the regions for geographical reasons. The Prairies, one of the most productive farming areas in the world, have provided an excellent location for a laboratory whose research has been directed towards agricultural problems. The location of the Atlantic Regional Laboratory is similarly appropriate to its work on marine plants and industrial metallurgy. The locations of the regional stations of the Division of Building Research were chosen because of their suitability for studying particular problems, e.g., research on avalanches in British Columbia. British Columbia also offers some of the best sites in Canada for astrophysical observatories. In addition to existing telescopes, proposals for new observatories have recommended sites in British Columbia.

2.4(c) Investigation of Regional Problems

NRC Laboratories assist in the investigation of regional problems and phenomena through the work of regional laboratories in the Maritimes and the Prairies, and through projects conducted in the field stations of the Division of Building Research and the laboratories in Ottawa.

During the past seven years, the main contributions

of the Atlantic Regional Laboratory have been work on marine algae, part of which is described in a case history in section 2.9, and research at high temperatures that is appropriate to regional problems of steel making, glass making, and the fabrication of ceramics. The work of the Prairie Regional Laboratory on rapeseed has provided an important crop and industry for the region while satisfying a large part of the national market for vegetable oil. Its work on legume seeds offers an alternative crop not only for the Prairies, but also for other regions of Canada.

The following examples illustrate other regional problems and phenomena that NRC Laboratories investigate:

- Staff from the Atlantic Regional Laboratory served on the team that cleaned Chedabucto Bay after the Arrow oil spill in February 1970. They measured the effect of the oil on living organisms, the combustion of oil, the degradation of oil on littoral rocks, and the absorption of oil by peat moss. They also devised an apparatus to steam clean fouled fishing gear. The library assembled technical information.

- The protection of buildings and highways from avalanches is expensive in the areas of high snowfall in British Columbia. NRC has measured the physical characteristics of avalanches. This knowledge is used to predict avalanches and to design protective structures. It is communicated to users through instructional courses.
- There is a great deal of coal in the Maritimes that suffers from the environmentally undesirable properties of high concentrations of ash and sulphur. A NRC process adds oil to a suspension of finely ground coal and water. The coal and oil form into spherical agglomerates, leaving much of the ash and sulphur behind.
- The effect of proposed modifications of harbours and waterways can be evaluated in advance using dynamic scale models built in NRC Laboratories. The lower Churchill River in Manitoba, the Miramichi Channel in New Brunswick, and the harbour at Port-aux-Basques in Newfoundland have been studied recently. A case history of the investigation of the Miramichi Channel is included in section 2.9.
- The present method of hot-water extraction of bitumen from the Athabasca Tar Sands produces water contaminated by clay and oil that can damage the environment.

The water is stored in ponds. A NRC process under development uses solvent extraction to discharge the sand and clay as clean spherical agglomerates with no waste water. The economics of the process will be established after construction of a pilot plant. A case history of this process is included in section 2.9.

The Office of Grants and Scholarships helps the investigation of regional problems mainly through its Negotiated Development Grants. For example:

- Dalhousie University has a negotiated development grant for research on coastal zone productivity.
- The University of Saskatchewan has a similar grant for research on the automatic control of agricultural processes.
- The University of Sherbrooke has a grant to investigate the utilization of peat.

The Committee on Industrial Research Assistance appreciates the particular difficulties of the firms in various regions of the country and makes a special effort to help. For example:

- fish, Irish moss, and plastics in the Maritimes,
- sporting goods and textiles manufacture in Quebec,
- legume crops, poultry, and electronic products in the western provinces.

In many instances, small firms are thriving as the result of the research work encouraged by the program.

The services supported under the Scientific and Technical Information Program are provided in cooperation with local organizations. This division of labour helps these local organizations and services to meet local needs. The field services of the Technical Information Service are provided under contract by Provincial Research Councils or Foundations in six provinces, helping them to extend the range of services available in their regions.

2.4(d) Role in Regional Development

The role of the NRC Regional Laboratories in Halifax and Saskatoon is to identify regional problems and to conduct research to solve them. The role of the Field Offices of the Canada Institute for Scientific and Technical Information is to seek and respond to enquiries by providing technical information and liaison with researchers in NRC Laboratories and elsewhere.

The success of the two Regional Laboratories demonstrates that the concept of dispersion of scientific activity across the country is sound, provided that the Regional Laboratories are:

- large enough to perform effective research and development,
- engaged in activities with a well-defined focus,

- located where they can interact profitably with local universities, industries, and other research establishments,
- supported by the broad expertise of the central NRC Laboratories and the resources of the Canada Institute for Scientific and Technical Information.

In view of the bicultural nature of Canada, the National Research Council considers that its role should be strengthened by the establishment of a laboratory in the Province of Quebec. In addition to contributing to regional development, the existence of such a laboratory would enable French-speaking Canadians to pursue a scientific career in a NRC Laboratory without leaving their cultural milieu.

The present, dangerously low level of Canadian research and development may perhaps best be corrected during the next decade by establishing more NRC Laboratories in other parts of the country.

The regional role of the Industrial Research Assistance Program is to assist firms to develop products appropriate to their region, as may be appreciated from the examples given in section 2.4(c).

The Office of Grants and Scholarships has a special program of Regional Development Grants (1.9 million dollars in the fiscal year 1975-76). The role of this

program is to assist in the development of emerging research groups in the francophone universities in Quebec and in some universities in the Maritime provinces.

2.4(e) Costs, Benefits, Conditions

Scientific research depends on the generation of ideas. Direct personal contact is highly desirable and often essential for the development of ideas. An important cost for a regional laboratory is the money and time required to maintain adequate personal contact with the scientific community or the alternative loss of momentum, enthusiasm, and ideas that results if insufficient money or time is devoted to this activity. A related and costly requirement is that the research groups should exceed a minimum critical size.

An important condition for success is the existence of effective links with the people and industries in the region. The greatest benefit occurs when collaboration between a strong regional laboratory and local industries and universities is supported by fiscal and industrial strategies that allow successful commercial exploitation of research results.

## 2.7 *Research Policies*

### 2.7(a) *Units Concerned with Intramural Research Activities:* THE NRC LABORATORIES

#### 2.7(a) 1. The Selection and Initiation of New Projects

Proposals for new research projects either originate within NRC Laboratories or arise from NRC's interactions with other federal government departments or agencies, provincial research organizations, industry, the university community, or individual professionals from related disciplines. All proposals are reviewed with respect to the following considerations:

- The priority of the relevant program element,
- The chances of scientific, technical, and economic success,
- The significance of success and the perceived benefits,
- The relationship to ongoing projects,
- The external sources of appropriate expertise,
- The federal government's Make-or-Buy Policy,
- The role of other federal government departments or agencies,
- The availability of intramural resources and expertise.

The selection and initiation of projects are based on defined roles, policies and program objectives. However, just as the proposals for new projects vary in scale, scope and resource

requirement, so the processes of selection and initiation vary according to the nature of the proposal. The processes for a particular project depend on such factors as:

- The scale of the project,
- The requirement for new or reallocated resources,
- The agreed role of NRC,
- The relevant program element,
- The source of the proposal,
- External interests.

The complexity of the processes and the levels of management involved, as well as the degree of involvement of other organizations, tend to increase with the scale and scope of the project. Three broad categories exist in practise:

(i) The simplest procedure is that for short projects which can be funded by existing resources. Selection and initiation is at the discretion of the laboratory director or section head, or, as is often the case in basic research, at the discretion of the individual researcher.

(ii) Many new projects require additional resources or reallocation of existing resources. The consideration of these proposals is a continuous process, but in most cases selection and initiation are phased with the budgetary cycle. Research priorities are

implemented through these decisions and, although the initial focal point is the Tactical Studies Committee, all levels of management are involved.

(iii) Proposals for major projects that may involve other organizations, either Canadian or foreign, are subject to a complex procedure of selection and initiation in which the Council and senior management consult with other federal departments or agencies, or with industry.

2.7(a) 2. Research Priorities

The NRC Laboratories respond to changing needs through the designation, evaluation, and implementation of priorities within their program. The considerations involved in the assessment of current priorities and the establishment of new priorities are:

- National needs,
- Regional needs,
- Federal government goals and objectives,
- NRC's objectives and sub-objectives,
- The role of NRC vis-à-vis other government departments, industry, and universities.

Priorities are implemented either through the allocation of new resources or the reallocation of existing resources. However, the response to a change of priorities can be a relatively slow process, determined partly by the response time of the budgetary cycle

and partly by the problems inherent in terminating existing projects or quickly changing their direction. These problems are discussed in section 2.7 (a) 6.

2.7(a) 3. Project Planning and Monitoring

Although formal network methods such as CPN or PERT are not in general use for the planning and monitoring of individual projects, NRC has established mechanisms and units for the coordination, planning, and monitoring of projects within the new program structure. Overall monitoring and review of all projects forms an integral part of the annual budgetary cycle.

In addition to normal management of research projects by laboratory directors and the Tactical Studies Committee, coordinators have been appointed for NRC's work in certain projects, for example, the federal government's Energy Project. Another mechanism is the appointment by Council of ad hoc external review committees to evaluate the research done by the NRC Laboratories.

The work of the Atlantic Regional Laboratory, the Division of Building Research, the Division of Mechanical Engineering, and the Prairie Regional Laboratory is monitored by Advisory Boards composed of members from other organizations who are distinguished in appropriate fields. The work of the staff of NRC Laboratories that is published in scientific and engineering journals is subject to critical review by independent referees selected by the editors. This provides an effective mechansim

of monitoring the quality of research, especially that of basic research. Finally, the programs of the National Research Council are reviewed annually by the Secretariat of the Treasury Board.

2.7(a) 4. "Contracting Out" Policy

The implementation of this policy by NRC is described under the following headings (i) Pilot Industry-Laboratory Program, (ii) Unsolicited Proposals, and (iii) Direct Contracts with Industry or University.

(i) Pilot Industry-Laboratory Program

The objective of the program is to assist in the application of research results, especially those of NRC Laboratories, to situations where there are important Canadian industrial opportunities. The program assists in the transfer of technology to Canadian industry.

The funds are used to help Canadian companies realize specific industrial opportunities arising from scientific and technical developments in the NRC Laboratories. The work normally comprises R&D or pilot studies by the company designed to test and develop a specific application. Each case is covered by a contract or research agreement.

The work supported under this program is normally of the type that would closely follow patent application or publication by NRC staff. Therefore assistance from an interested NRC division is essential for the success

of projects under the program. This assistance ranges from simple advice and consultation, through technical guidance, to direct involvement in the R&D as a partner.

The following projects are supported by the Pilot Industry-Laboratory Program:

- Analytical Photogrammetric Plotter (Instronics Ltd., Stittsville, Ontario): to advance the technology and establish a practical design.
- Triply Redundant Clock (Edmunde Newhall Associates Ltd., Rexdale, Ontario): to design and construct a triply redundant clock code generator to compare three cesium clocks and transmit a concensus time signal (Case history, page 265).
- Film-Coating Prototype (Sentrol Systems Ltd., Toronto, Ontario): to mass produce optical multilayer coatings for the prevention of counterfeiting (Case history, page 309).
- Diagnosis of Gonorrhoea (M.D.S. Health Group Ltd., Toronto, Ontario): to develop commercial clinical tests for the diagnosis of gonorrhoea (Case history page 259).
- Tar Sands (Terra Energy Ltd., Calgary, Alberta): to extract bitumen from Alberta Tar Sands by spherical agglomeration (Case history, page 313).
- Snack Foods from Pea Products (Pro-Star Mills Ltd., Saskatoon, Saskatchewan): to develop a commercial

process for the production of snack food chips from field pea flour (Case history, page 332).

- Tuneable Gas Laser (Lumonics Research Ltd., Kanata, Ontario): to develop a commercial high-power laser (Case history, page 306).

(ii) Unsolicited Proposals for Research and Development

Unsolicited proposals are administered by the Science Procurement Sector of the Department of Supply and Services. The proposals, which may come either from industry or university, are circulated to various departments. If a department is interested in sponsoring the proposal, it must commit funds thereto, although the Department of Supply and Services may provide temporary "bridge funding."

The National Research Council has established an Industrial Programs Office to expedite consideration of these proposals, and to provide a focus for liaison with the Department of Supply and Services.

The following projects resulted from Unsolicited Proposals:

- Study of the Potential for Solar Heating of Buildings in Canada (University of Waterloo, Ontario).
- Development, Construction, and Testing of a Vertical Axis 200 kW Wind Turbine (Dominion Aluminum Fabricating Ltd., Mississauga, Ontario).

- Soil Disturbance from Pile Driving in Sensitive Clay (Terratech Ltd., Montreal, Quebec).
- Instrumentation of a Water Intake Tunnel Deep in Bedrock (William Trow Associates, Rexdale, Ontario).
- Development of a Pulsed TEA laser for Paper Cutting (Gen-Tec Ltd., Quebec, Quebec).

(iii) Direct Contracts with Industry or University

In addition to the foregoing programs, there are many examples of specific projects being contracted-out by individual NRC divisions to industry or university. A notable example is provided by the Division of Biological Sciences, which has let research contracts to obtain new information needed in the establishment of scientific criteria on the effects of environmental pollutants by the Associate Committee on Scientific Criteria for Environmental Quality (Table 2.7.I).

A sample of contracts let by the National Research Council in support of its laboratory research programs is presented in Table 2.7.II.

2.7(a) 5. (i) Extramural Research Policies

The extramural research policies of NRC Laboratories are outlined above, in section 2.7 (a) 4. However, two NRC programs (Scholarships and Grants in Aid of Research, and Industrial Research Assistance) are concerned exclusively with extramural reserarch, and their policies are discussed in section 2.7.(b).

TABLE 2.7.I CONTRACTS LET BY DIVISION OF BIOLOGICAL SCIENCES ON BEHALF OF THE ASSOCIATE COMMITTEE ON SCIENTIFIC CRITERIA FOR ENVIRONMENTAL QUALITY

| | |
|---|---|
| QUIC/LAW - Professor H. Lawford | Queen's University Kingston |
| Mercury contamination of fish and aquatic birds in Northwestern Ontario. | Acres Consulting Services Ltd. |
| Biological, chemical and biochemical effects of pesticidal seed dressings on seed-eating birds. | Dr. J.G. Saha, CDA, Saskatoon. |
| Water quality criteria for heavy metals and mine wastes in relation to fish. | Drs. F.W.H. Beamish and J.B. Sprague, University of Guelph, Guelph, Ont. |
| Studies on Freshwater Algae | Dr. D.R. Cullimore, University of Regina. |
| Study of Mechanism of Carcinogenesis by Polycyclic Aromatic Hydrocarbons | Drs. R.H. Haynes and M. Katz, York University, Downsview, Ont. |
| Particle size distribution of suspended particulate matter in relation to polynuclear aromatic hydrocarbon content. | Dr. M. Katz, York University. |
| The dosimetry of environmental polycyclic hydrocarbons. | Dr. M. Katz, York University. |
| Significance of bird blood parasites and their biting fly vectors as indicators of environmental quality. | Dr. M. Laird, Memorial University, St. John's, Newfoundland. |
| Assessment of long-term effects of air pollutants on vegetation and simple ecosystems. | Professor V.C. Runeckles, University of British Columbia. Vancouver, B.C. |
| Enterovirus dissemination in marine and waste water. | Dr. D.M. McLean, University of British Columbia, Vancouver, B.C. |
| A study of the feasibility of using an in-field bioassay system for picloram in which an alga is the indicator organism. | Dr. D.R. Cullimore, University of Saskatchewan, Regina Campus. |
| The use of major health care data sources in identifying the effects of the human environment on health: a feasibility and pilot study in Saskatchewan. | Dr. C.A.R. Dennis, Regina Community Health Clinic Regina, Saskatchewan. |
| Biological effects of polycyclic aromatic hydrocarbons and related environmental pollutants. | Dr. M. Katz and Dr. R.H. Haynes, York University. |
| Zinc and copper toxicology in marine fish. | Dr. G.L. Fletcher, Marine Sciences Research Laboratory, Memorial University, St. John's, Newfoundland. |

TABLE 2.7.II. CONTRACTS LET BY NRC LABORATORIES

| | |
|---|---|
| Development of a data logger for wave recording programmes. | George Sanders, Geophysics Ltd Kanata, Ontario. |
| Development and construction of specialized equipment for sediment transport studies. | Metalpro, Renfrew, Ont. |
| Survey of Miramichi Estuary, N.B. | In combination with DREE and the Province of N.B. to Comdev Marine Ottawa, Ont. |
| Design of wave generators for model and research work. | Flynn-Elliott and Associates |
| Development of predictive method of air cushion vehicles (ACV) overload drag estimations. | J. Decker, Consultant |
| Axial compressor analysis: for specialized compressor flow analysis. | Carleton University |
| Engineering acoustic research facility. | University of Toronto Institute of Aerophysics for acoustical model analysis, and with Bolt, Beranek and Newman Inc. for acoustical design. |
| Canada-France-Hawaii Telescope - engineering design and construction. | S.N.C. Group, Montreal; Brittain Steel, Vancouver; Canadian Marconi, Montreal. |
| Photon Counting TV Systems | University of British Columbia |
| Image Slicer | Scott Plastics |
| Small Spectographs | Advance Industries |
| Economic appraisal of the dulse industry in the Atlantic Provinces. | Professor R.A. French |
| Natural convection on the outside surface of buildings. | University of Waterloo |
| Evaluation of a lighting power budget for energy conservation. | Mr. W.E. Wotton |
| Information retrieval and thesaurus development. | University of Montreal |
| Preparation of a report on durability and performance of protective coatings. | Dr. M. Yaseen |

TABLE 2.7.II continued

| | |
|---|---|
| Feasibility study of moisture detector manufacture. | Bell Northern Research Ltd. |
| Teleoperator Remote Manipulator Systems.<br>A cooperative space program between the United States National Aeronautics and Space Administration and NRC for the development and procurement of a Space Shuttle Attached Remote Manipulator System (RMS). NRC in conjunction with DSS has contracted the research and development, design manufacture and detailed management of the RMS project to a Canadian industrial team. | Spar Aerospace Products Ltd. - prime contractor.<br>CAE Electronics Limited<br>RCA Limited<br>Dilworth, Secord and Meagher Associates Limited. |

(ii) <u>The Role of Other Federal Agencies</u>

Other federal departments or agencies influence NRC's intramural research in various ways. It is, for example, NRC policy to complement the work of other departments or agencies by:

- Sharing its facilities, e.g., wind tunnels,
- Providing research in support of a department's mission, particularly when the department has no laboratory of its own,
- Participating in integrated federal programs.
- Participating in interdepartmental advisory and coordinating committees.

In addition, it is NRC policy to consult regularly with departments concerned with science policy, e.g., Ministry of State for Science and Technology and the Science Council, especially during the formulation of research policies, the establishment and review of priority areas, and the selection of new research projects.

2.7(a) 6. <u>The Shifting of Research Resources</u>

As described in section 2.7 (a) 2., NRC implements its priorities through the allocation of new resources or the reallocation of existing resources. When new resources are made available, the response to a new priority can be rapid. However, the implementation of a new project at the expense of existing projects may be slower if the change requires reassignment of highly

specialized research staff. Although recent graduates can usually be transferred readily within their own disciplines, there is a general tendency for scientists to become experts in specialized fields as their research experience increases. An experienced scientist is therefore somewhat reluctant to transfer to another subdiscipline, where he would be less able to exploit with advantage his acquired knowledge and expertise. This problem can be alleviated to a limited extent by encouraging research staff to change their field several times during their career. This can be very rewarding intellectually to the individual and productive for the organization. On the other hand, to force a change in research interest is in most cases counterproductive. Experience has shown that scientists can be encouraged to meet changing requirements by offering incentives, which may include opportunities to:

- Respond to a new challenge (the strongest motivation for scientists and engineers),
- Participate in a project of obvious social, technological, or economic benefit,
- Acquire valuable experience in new fields of research,
- Work on a project which will be financially well supported,
- Collaborate with researchers in other organizations.

An additional difficulty in shifting research resources is the fact that new projects are likely to require new and specialized equipment. If the equipment is expensive or new facilities are required, there is a delay while extra funds are sought from the reduction or termination of existing projects.

Despite these difficulties, several groups within NRC have successfully accomplished major changes in direction in recent years. This is a continuing process in all areas of the intramural research program.

2.7(a) 7. Transfer of Research Results

The main methods of transfer of intramural research results are personal contacts (the most effective method), publication in scientific or engineering journals, publication as laboratory reports or patents, and presentation of papers at conferences or seminars. The NRC Laboratories in recent years have published annually more than 1,000 articles and reports (details in section 2.8). However, it is an unfortunate fact that simply publishing the results of a research project does not guarantee that the results will reach those having need of them. This is particularly true in the case of transferring the results of applied research to industry.

NRC attempts to overcome these difficulties by:

- Ensuring close collaboration between the work of NRC Laboratories and the information networks developed

by the Canada Institute for Scientific and Technical Information,

- Ensuring liaison between laboratory personnel and the various Associate Committees of Council,
- Supplying industry with lists of publications and laboratory reports,
- Organizing informal seminars or meetings in selected fields of science and engineering.

The National Research Council emphasizes the transfer of technology from its Laboratories to industry. In addition to personal consultation with its laboratory staff, the National Research Council has developed the mechanisms for the transfer of technology that are described in section 2.7 (a) 4.

2.7(b) *Units Exclusively Concerned with Extramural Research Activities:*

The National Research Council has two programs concerned exclusively with extramural research activities. These are (I) the program of Scholarships and Grants in Aid of Research and (II) the Industrial Research Assistance Program. These two programs support, respectively, research in universities and industry.

2.7(b) (I) SCHOLARSHIPS AND GRANTS IN AID OF RESEARCH

The fundamental objectives of the National Research Council in awarding grants and scholarships are to support the development and maintenance of broadly based research

competence in the natural sciences and engineering in Canadian universities and to support the formation of highly qualified manpower in these fields. The Council, with the assistance of its Committee on Grants and Scholarships, develops programs of grants and scholarships, and the policies to be applied in their implementation.

The Office of Grants and Scholarships implements the policies and procedures developed by Council for the use of the funds provided under Parliamentary Vote Number 35, "Grants and Scholarships to Universities." The Office also administers a program to encourage collaboration in research between universities and industry, a program of fellowships to encourage doctoral graudates to seek industrial careers, and a NATO Science Committee Fund of approximately $190,000 a year.

The Annual Report on Scholarships and Grants in Aid of Research, 1974-75, is submitted as Exhibit 1.

2.7(b) (I) 1. Process of Acceptance

Applications for research grants from individual university researchers are assigned by discipline to the most appropriate of twenty-two Grant Selection Committees. Each committee is composed of between eight and thirteen members who are experts in the disciplines considered by the committee. The majority of the members of the committees are university professors.

Applications are considered by the committees once a year. Two or three members offer the committee detailed reviews of each application before the whole committee makes its decision. Committees also seek the opinion of reviewers who are not members of the committee, and arrange on-site visits as required.

The excellence of the researcher and of the proposal are considered by the committee in deciding awards to individual researchers. The record of achievement of the unit in which the researcher works may be considered in the assessment of applications for major equipment costing more than $50,000 that is intended for use by a team of researchers.

The following types of grant are adjudicated by committees of experts who assess the merits and likelihood of success of the proposals:

- Negotiated Development Grants: large consolidated grants awarded to groups of researchers to establish special research capabilities in promising areas of study,
- Projects of Research Applicable to Industry: grants which enable university researchers to develop an idea to the stage at which it can be taken over by a company.

2.7(b) (I) 2. <u>Establishment of Priorities</u>

There are two levels of priorities. The first level provides an appropriate allocation of the available funds among the various disciplines represented by the Selection Committees. The second level determines the value of the individual project grants made by the Selection Committees.

The distribution of funds between the selection committees is made by Council following recommendations of the Committee on Grants and Scholarships, which are developed by its Subcommittee on Allocations. These recommendations are based on advice concerning the effectiveness of and the requirements for the various types of grants and scholarships. This advice originates with the Council's Advisory Committees, the Selection Committees, and the research community at large.

Priorities among the individual applications are established by the Selection Committees on the basis of policies approved by Council.

2.7(b) (I) 3. <u>Monitoring and Evaluation</u>

Grants to individual researchers are monitored annually, mainly by the review of progress reports, publications, patents, and presented papers that arise from the work. Major projects are monitored through visits by representatives of the Grant Selection

Committees or the Office of Grants and Scholarships or both.

2.7(b) (I) 4. Implementation of Priorities

The priorities established by Council and the Committee on Grants and Scholarships are implemented by this committee in its allocation of funds to the various programs of grants and scholarships. The priorities established by the selection committees are implemented by acceptance of their recommendations of the sum of money to be awarded to each applicant.

2.7(b) (I) 5. CPN, PERT Network Methods

None.

2.7(b) (I) 6. Shifting of Resources

Changes in the allocation of research resources are made by Council on the recommendation of the Committee on Grants and Scholarships. A current example is the decision to suspend the program of Negotiated Development Grants for one year, due to financial constraints and the need to re-evaluate the program in this context.

2.7(b) (I) 7. Transfer of Research Results

The primary method of transferring university research results to those having potential need of them is by means of publications in scientific and engineering journals. In addition, the results of work conducted with the aid of grants for Projects of Research Applicable

in Industry are transferred directly to industry.

2.7(b) (I) 8. Funds Expended/Available

All the funds made available annually are expended.

2.7(b) (I) 9. Funds Granted/Requested

Total funds granted represent close to 50% of the total funds requested.

2.7(b) (II) THE INDUSTRIAL RESEARCH ASSISTANCE PROGRAM

The Industrial Research Assistance Program was authorized by Cabinet in November 1961 and the National Research Council was made responsible for administering the program on 1 April 1962. The original authorization of the program defined its purpose as follows: "To establish a number of competent research teams in industry each year over a period of years. The R&D projects submitted by industry should be judged on their merits with this general purpose in mind." The original authorization also specified that the industry contribute at least half the cost of a project, but that all rights arising out of the research should be the property of the company concerned.

A Committee on Industrial Research Assistance was set up by NRC to review policies and procedures for the administration of the program, to screen applications, and to approve financial aid. This committee is composed of senior staff from NRC and from other government agencies that have a direct interest in industrial

research, including Agriculture Canada, the Department of Energy, Mines, and Resources, Environment Canada, Communications Canada, the Department of National Defense, the Department of Industry, Trade, and Commerce, and the Treasury Board.

2.7(b) (II) 1. Process of Acceptance

Grants are awarded following detailed review of each project by the Committee on Industrial Research Assistance. The Committee is served by a secretariat which advises companies on the terms and conditions of the program and obtains expert opinions on each proposal for consideration by the committee. The secretariat obtains information for the committee which includes the following factors:

- the record of achievement of established firms, or of individuals in new firms,
- the technical merit of the proposal,
- the plans of the company to use the results of the research commercially,
- the ability of the company to fulfil the plans successfully.

The allocation of funds is competitive, with grants being awarded to projects which best satisfy the priorities of the program. Competition is ensured by deliberately considering together a number of diverse projects.

2.7(b) (II) 2. Establishment of Priorities

The Committee on Industrial Research Assistance decides which industries are most likely to benefit from research assistance at any given time and the relative merits of assisting small and large companies. Priorities derived from these decisions are applied in the acceptance of proposals.

Within these broad guidelines, priority is given to projects that have great technical merit, that involve significant risk, but that offer substantial economic and social benefits if successful. Application of these priorities is calculated to improve the calibre and scope of the participating industrial R&D teams.

2.7(b) (II) 3. Monitoring and Evaluation

The progress and prospects for success of a project are assessed by representatives of the Committee on Industrial Research Assistance through visits to the project as required. These representatives are federal public servants bound by an Oath of Office and Secrecy to respect confidentiality. Discretion is observed in their assignments to avoid possible conflicts of interest between different and possibly competing firms.

Approximately 180 scientists and engineers from government laboratories serve as scientific consultants and liaison engineers. Annual reports are prepared

both by the company and the liaison staff. The firm and the secretariat of the Committee on Industrial Research Assistance each prepare a final report upon completion of a project.

2.7(b) (II) 4. Implementation of Priorities

The priorities established by the Committee on Industrial Research Assistance are implemented by this committee in its awards of grants for specific projects.

2.7(b) (II) 5. Network Methods

It is the responsibility of a firm to review the progress of its project in detail and to report to the secretariat. Several firms employ CPN or PERT methods. However, the purposes of the Committee on Industrial Research Assistance are satisfied by the measurement of progress towards predetermined goals at intervals of between three months and one year, depending on the duration of the project.

2.7(b) (II) 6. Shifting of Resources

Great emphasis was at one time placed on "good science" and "peer assessment" in the award, modification, and termination of grants by the Committee on Industrial Research Assistance. More weight is now given to market needs and opportunities, including the firm's prospects for eventual commercial success. Company managements are usually highly sensitive to

changes in such factors and it is relatively easy to reach agreement to change a project or to terminate it if these factors become adverse.

2.7(b) (II) 7. Transfer of Research Results

The research is performed in industry, with a commercial motive to exploit the results.

2.7(b) (II) 8. Funds Expended/Available

Cash expenditures are usually close to the target.

2.7(b) (II) 9. Funds Granted/Requested

Many proposals, before formal submission to the Committee on Industrial Research Assistance, are rewritten after consultation with the secretariat. Of the funds formally requested from the committee, between 75 and 80% are granted.

## 2.8 *Research Output*

### 2.8 1. Patents

The number of patents granted to staff of the NRC Laboratories, the licences issued, and the value of resulting production are presented in Table 2.8 1. I. The titles and inventors of these patents are presented in Table 2.8 1. II.

An analysis of the number of patents and licences, and the value of resulting production, is not readily available for the 5,000 university researchers who receive research grants from the National Research Council. The output of university research is overwhelmingly through publication in research journals. Nevertheless, grantees are encouraged to patent the results of their research and to make use of the services of Canadian Patents and Development Limited.

TABLE 2.8 1. I. NRC PATENT STATISTICS 1968-76

| | | 1968/69 | 1969/70 | 1970/71 | 1971/72 | 1972/73 | 1973/74 | 1974/75 | 1975/76 |
|---|---|---|---|---|---|---|---|---|---|
| Canadian patents and patent applications | | 15 | 13 | 17 | 9 | 18 | 12 | 12 | 1 |
| Foreign patents and patent applications | | 22 | 30 | 21 | 28 | 25 | 28 | 16 | 2 |
| New Canadian Licenses | | 6 | 6 | 8 | 5 | 5 | 7 | 2 | Nil |
| New Foreign Licenses | | 1 | 1 | Nil | Nil | Nil | Nil | 1 | Nil |
| Yearly value of production from all NRC licenses $000's | Canadian | 589 | 685 | 721 | 666 | 914 | 824 | 983 | N/A |
| | Foreign | 559 | 590 | 493 | 436 | 624 | 703 | 544 | N/A |

TABLE 2.8 1. II. TITLES OF PATENTS GRANTED OR PENDING, 1968 to 1975

| Title | Inventor(s) |
|---|---|
| Lytic Enzymes from Sorangium | D.R. Whitaker |
| Benzoylation of Deae - Dextrans (Sephadex) | S.A. Narang<br>J.J. Michniewicz |
| Meningococcal Vaccine | H.J. Jennings<br>P. Kenny (NHW) |
| 1-Hydroxy-6-Methoxy Phenazines | F.D. Cook<br>O.E. Edwards<br>D.C. Gillespie<br>E.R. Peterson |
| Alkylation Process | B.V. Gregorovich<br>S.F. MacDonald |
| Co-Pelletizing Salt Mixtures with Composite Brine Binder | C.E. Capes |
| Continuous Countercurrent Cone Agglomerator | F.W. Meadus<br>B.D. Sparks<br>I.E. Puddington |
| Separation of Silicates from an Ilmentite Concentrate (Agglomeration) | B.D. Sparks |
| Separation of Barite by Agglomeration | F.W. Meadus<br>I.E. Puddington |
| Preparation of Rubber-Reinforcing Amorphous Silica | A.F. Sirianni<br>N.A. Funnell<br>I.E. Puddington |
| Bacterial Oxidation and Agglomeration of Pyritic Coal | A.F. Sirianni<br>A.E. McIlhinney<br>C.E. Capes |
| Increasing Permeability of Reverse Osmosis Membranes | J. Kopecek<br>S. Sourirajan |
| Cationic Polymerization of Ethylene and Catalyst | S. Brownstein |
| Thiocarbohydrazone Fungicides for Cellulosic Material | D.M. Wiles<br>T. Surprunchuk |

TABLE 2.8 1. II. PATENTS (continued)

| Title | Inventor(s) |
|---|---|
| Antibiotic Cochliodinol and Production by Chaetomium | D. Brewer<br>A. Taylor<br>W.A. Jerram |
| Bacterial Oxidation in Upgrading Sulfidic Ores and Coals | A.E. McIlhinney<br>A.F. Sirianni<br>C.E. Capes<br>I.E. Puddington |
| Agglomeration and Extraction of Peat Moss | M.J.M. Ruel<br>A.F. Sirianni |
| Apparatus for Making Tubular Polymeric Membranes for Reverse Osmosis | W.L. Thayer<br>L. Pageau<br>S. Sourirajan |
| Composite Metal Bird Shot | F.W. Meadus<br>B.D. Sparks<br>I.E. Puddington |
| Removal of Pigment from De-Inked Paper | I.E. Puddington<br>B.D. Sparks |
| Electroluminescent Diode Device | D.F. Williams<br>M. Schadt |
| Preparing Reverse Osmosis Membranes | B. Kunst<br>S. Sourirajan |
| Photostabilization of Polymers | D.J. Carlsson<br>T. Suprunchuk<br>D.M. Wiles |
| Forming Uniform-Sized Agglomerates | C.E. Capes<br>R. Coleman<br>W.L. Thayer |
| Dense Phase Vertical Pneumatic Conveying | C.E. Capes<br>A.E. McIlhinney<br>T.A. Tweddle |
| Agglomeration of Sand and Clay from Tar Sands | F.W. Meadus<br>B.D. Sparks<br>I.E. Puddington |

TABLE 2.8 1. II. PATENTS (continued)

| Titles | Inventor(s) |
|---|---|
| Bonding Condensation Polymers to Polyolefin Base | P. Blais<br>D.M. Wiles<br>D. Carlsson |
| Beneficiation of Coals | C.E. Capes<br>A.E. McIlhinney |
| Isopropenyl Acetate Polymers and Process | S. Bywater<br>E. Whalley |
| Spherical Agglomeration Process | C.E. Capes<br>J.P. Sutherland<br>A.E. McIlhinney |
| Electrolytic Formation of Films of $Fe_2O_3$ | M. Cohen<br>P.B. Sewell |
| Catalysts Having Stable Free Radicals Containing Sulfur | Z.F. Dudzik |
| Microporous Carbon Preparation | B. Evans<br>E.A. Flood |
| Extraction of Tin from Tin-Containing Ores | J.R. Farnand<br>F.W. Meadus<br>I.E. Puddington |
| Method of Producing Lignin-Reinforced Rubber | T.R. Griffith<br>E.C. Horswill<br>D.W. MacGregor |
| Injection of Electric Charge Carriers into Non-conducting Materials | W. Helfirch<br>W.C. Schneider |
| Oxidation of Olefins to Epoxides | K.U. Ingold<br>F.W. Meadus |
| Method and Apparatus for Conveying Particulate Material Upwardly in a Gas Stream | C.E. Capes |
| Method and Apparatus for Ball Agglomerating Particulate Material | C.E. Capes<br>W.L. Thayer<br>R.D. Coleman |

TABLE 2.8 1. II. PATENTS (continued)

| Titles | Inventor(s) |
|---|---|
| Laundered Amorphous Reinforcing Lignin | A.F. Sirianni<br>I.E. Puddington |
| Aromatic Dextran Derivatives | S.A. Narang<br>J.J. Michniewicz |
| Hollow Spherical Particles | J.R. Farnand<br>I.E. Puddington |
| Fluid Transfer Apparatus | R.N. Jones<br>J.M.A. Nadeau |
| Reduction of Efflorescence in Composite Agglomerates | C.E. Capes<br>A.E. McIlhinney |
| Perforated Hollow Packings in Fluidized Beds | A.E. McIlhinney<br>G.L. Osberg<br>J.P. Sutherland |
| Agglomerated Metal Shot | F.W. Meadus<br>I.E. Puddington |
| Forming Balls from Powder | A.F. Sirianni<br>I.E. Puddington |
| Process for Separation of Siliceous and Phosphatic Materials from Iron Bodies | A.F. Sirianni<br>I.E. Puddington |
| Recovering Phosphoric Acid | A.F. Sirianni<br>I.E. Puddington |
| Rain Repellent Composition | D.F. Stedman |
| Production of Amorphous Ferric Oxide | D.F. Stedman |
| Reaction of a Gas with a Solid | D.F. Stedman |
| Dissolution of Potassium Chloride Ores in Solution Mining | J.B. Taylor<br>M.R. Hunt |
| Ground Detector with Low Detector Hazards | M.P. MacMartin |
| Simple Linear Pulse to Pulse Tachometer | O.Z. Roy<br>R.W. Wehnert |

TABLE 2.8 1. II. PATENTS (continued)

| Title | Inventor(s) |
|---|---|
| Line Isolation Monitor | M.P. MacMartin<br>N.L. Kusters |
| Current Transformer with Internal Solid-State Error Compensator | P. Miljanic |
| Hot-Cathode Ionization Gauge | P.A. Redhead |
| Voltage Controlled Oscillator | D. Rocheleau |
| Improvements to Compararator Bridge | N.L. Kusters<br>M.P. MacMartin |
| Digital Bit-Timing Recovery Servo | F.E. Vachon |
| Automated Slide-Screw Tuner | A.L. VanKoughnett |
| Ink Line Dryer | A.L. VanKoughnett |
| Self-Q-Switching of Ruby Lasers | A. Szabo |
| Improvements in High Voltage Capacitance Bridge | N.L. Kusters |
| Pseudo-Random Rhythm Generator | J.K. Pulfer<br>T.H. Shepertycki |
| Thermal Transpiration Vacuum Pumps | J.P. Hobson |
| Resistance Measuring Bridge Using a Direct Current Comparator | N.L. Kusters<br>M.P. MacMartin |
| Current Comparator for Power and Energy Measurement | N.L. Kusters<br>W.J.M. Moore |
| Automated Triple Stub Tuner for Resonant Microwave Heating Systems | A.L. VanKoughnett<br>W. Wyslouzil |
| Low Leakage Isolating Transformer for Electromedical Apparatus | N.L. Kusters<br>M.P. MacMartin |
| Microwave Absorption Moisture Gauge | A.L. VanKoughnett |
| Computer-Controlled Photoelectric Tristimulus Color-Meter | A. Staniforth<br>J. McDougall<br>A.R. Robertson<br>D.S. Gignac |

TABLE 2.8 1. II. PATENTS (continued)

| Title | Inventor(s) |
|---|---|
| Echoencephalograph | A.C. Hudson<br>B.J. Trollope |
| Parallel Plate Drying Chamber | A.L. VanKoughnett |
| Tone Burst Ranging System for Parallel-Line Sounding | W. Wyslouzil |
| Biopotential Analog | G. Schuler |
| Improvement to Forest Cover Radar | R.L. Westby |
| Waveguides | W.J. Bleackley |
| Indicating by Microwave Energy the Constituent Proportions of a Flowing Substance | W.J. Bleackley |
| Microwave Apparatus for Determining the Characteristics of a Sample | W.J. Bleackley<br>R.W. Breithaupt |
| Method and Apparatus for Dielectric Heating | W.J. Bleackley<br>W.A. Cumming |
| Electronically Scanned Microwave Moisture Indicator | R.W. Breithaupt<br>W.J. Bleackley |
| Butter Water-Content Measuring Device | W.J. Bleackley |
| Microwave Dryer for Cylindrical Objects | W.J. Bleackley |
| Automatic RMS/DC Comparator | L.G. Cox<br>N.L. Kusters<br>M.P. MacMartin |
| Single-Mode Excitation in a Parallel-Plate Region or Oversize Waveguide | W.A. Cumming |
| Method and Apparatus for Dielectric Heating | W.A. Cumming |
| Branched Waveguide Transistors with with Mode Filters | W.A. Cumming |
| Microwave Dryer for Drying the Glue Line in Paper Forms | W.A. Cumming<br>W.J. Bleackley |

TABLE 2.8 1. II. PATENTS (continued)

| Title | Inventor(s) |
|---|---|
| Tone Color Changer | R. Farley |
| Pitch Sustaining Means for Key-Operated Monophonic Instrument | R. Farley<br>D. Rocheleau |
| Touch Sensitive Position Encoder Using a Layered Sheet | A.M. Hlady |
| Polyphonic Electronic Instrument | H. LeCaine<br>D. Rocheleau<br>R. Farley |
| Phantom Burden for Current Transformer Calibration | N.L. Kusters |
| Frequency Selective Optical Memory | A. Szabo |
| Communication System for the Handicapped | O.Z. Roy<br>J.R. Charbonneau |
| Low Noise Differential Amplifier for Measuring Biological Signals | G.T. Schuler |
| Electroencephalograph Having Meter Probe Movable in a Calvarium-Shaped Liquid Filled Tank and Method of Use | G.T. Schuler |
| Self-Balancing Current Comparator for Precise Voltage Levels and Potentiometer Usage | N.L. Kusters<br>M.P. MacMartin |
| Alternating Current Apparatus for Measuring Capacitance or Phase Angle | N.L. Kusters<br>W.J.M. Moore |
| Magnetic Flux Modulator for Direct Current Measurement | M.P. MacMartin<br>N.L. Kusters |
| Apparatus for Reduction of Semi-Conductor Reverse Current | P.N. Miljanic |
| Transistor Amplifier and Frequency Multiplier | J.K. Pulfer<br>A.E. Lindsay |
| Ionization Vacuum Gauge with X-ray Shielding and Ion Reflecting Beams | P.A. Redhead |

TABLE 2.8 1. II. PATENTS (continued)

| Titles | Inventor(s) |
| --- | --- |
| Superpositioning Image Slicer | E.H. Richardson |
| Data Receiver and Synchronizing System | F.J.E. Vachon |
| Microwave Heating Apparatus | A.L. VanKoughnett |
| Radar System and Circuits for Use Therein | R.L. Westby |
| Gas Detector | P.A. Redhead |
| Detector-Demodulator for Modulated (Reversed) ac and dc Signals | N.L. Kusters<br>M.P. MacMartin |
| Recorder for Acoustic Ranging System | W. Wyslouzil |
| Apparatus for Producing Complex Rhythm Patterns | J.K. Pulfer<br>T.H. Shepertycki |
| Tuning Means in a Microwave Heating Apparatus | A.L. VanKoughnett<br>W. Wyslouzil |
| Vacuum Artery Clamp | T.R. Ringer<br>H.T. Kimberley |
| Converter Gas Analyser | E.H. Dudgeon |
| Foamed Clay Material | G.A. Macaulay |
| Conductivity Measuring Probe for Smelting Processes | P. Savic |
| Draft Gear Key | G.A. Smith |
| Protection for Newsprint in Impacting Freight Cars | G.A. Smith |
| Strut Supported Echo Sounding System | S.T. Mathews<br>L.L. Kawerninski |
| Pulse Jet Engine to Heat Switches | J.F. Lane |
| Transparent Brain Container | C. Romero-Sierra<br>L. Caron<br>G. Beaudry |

TABLE 2.8 1. II. PATENTS (continued)

| Titles | Inventor(s) |
| --- | --- |
| Ice Detector | J.R. Stallabrass<br>D.L. Bailey<br>T.R. Ringer<br>P. Hearty |
| Process of Wound Healing | C. Romero-Sierra<br>S. Halton<br>J.A. Tanner |
| Liquid Level Height Transducer | C.M.G. Zwarts |
| Flexible/Rigid Surgical Dressing | C.A. Romero-Sierra<br>J.A. Tanner |
| Marine Coupling | S.T. Mathews<br>L.I. Kawerninski |
| Stowable Restraining Apparatus | C.A.M. Smith |
| Brain Biological Specimen Post-Mortem Inspection and Preserving Vessel | C.A. Romero-Sierra<br>L. Caron |
| Crash Sensitive Pulse Generator | H.T. Stevinson<br>D.A. Baker |
| Co-Flowing Jet Velocity Sensor | J.W. Tanney |
| Turbulence Measuring Device for Transport Aircraft | G.K. Mather<br>D.F. Daw |
| Nozzle/Receiver Fluid Densitometer | J.W. Tanney |
| Co-Axial Velocity Sensor | J.W. Tanney |
| Submarine Anomaly Simulator Using Solid-State Components | R.C. Baker |
| High Resolution Frequency to Voltage Converter | R.C. Baker |
| Over-Center Mechanism | H.T. Stevinson |
| Planetary Electrical Contact | T.M. Dauphinee |

TABLE 2.8 1. II. PATENTS (continued)

| Titles | Inventor(s) |
| --- | --- |
| Monocomparator | T.J. Blachut<br>A.J. Smialowski |
| Detection of UHF Light Modulation with a Photo-Multiplier | D.S. Smith |
| Relief Shading Process | Z. Marsik<br>T.J. Blachut<br>D.M. Makow |
| Turbine Compressor Noise Reduction | T.F.W. Embleton<br>G.J. Thiessen |
| Computer Program for Design of Glass Filter | H. Wright<br>C. Sanders<br>D. Gignac |
| Computer-Controlled Photoelectric Tristimulus Color Meter | A.R. Robertson<br>D.S. Gignac<br>A. Staniforth<br>J. McDougall |
| Ultraviolet Source for Laser Preionization | M.C. Richardson<br>C. Leopold |
| Variable Interference Reflector | G.R. Hanes<br>J.A. Dobrowolski<br>C.J. Van der Hoeven |
| Production of a Modified Ortho-photograph | S.H. Collins |
| Method and Apparatus for Measuring High Resistances | S.H. Tsao |
| Photogrammetric Projection Instrument | T.J. Blachut<br>G.H. Schut<br>A.J. Smialowski |
| Stereocompiler | T.J. Blachut<br>A.G. Amaro<br>M. Paulin |
| Orthocartograph | T.J. Blachut<br>A.J. Smialowski<br>G.H. Schut<br>P.D. Carman |

TABLE 2.8 1. II. PATENTS (continued)

| Titles | Inventor(s) |
|---|---|
| Identification Element | K.M. Baird<br>J.A. Dobrowolski<br>A.J. Waldorf<br>P.D. Carman |
| Improved Salinometer Circuit | T.M. Dauphinee |
| Direct Reading Thermometer Using DC Comparator Bridge | T.M. Dauphinee |
| Displacement Measuring Device Including a Spaced Four-Corner Electrode Array | D.M. Makow |
| Sheet Resistors Having Integral Tap Points | D.M. Makow |
| Method of Extending the Dynamic Range and the Sensitivity of a Data Acquisition System | H. Preston-Thomas<br>T.M. Dauphinee<br>J.D. Sankey |
| Photometer for Standardizing Color TV | C.L. Sander<br>G.W. Wyszecki<br>W.J. Gaw |
| Gaseous Laser of Improved Construction | K.M. Baird |
| Thermo Expansion Compensation Device | K.M. Baird |
| Method and Application for the Stabilization of Lasers, Etalons and Similar Optical Devices | K.M. Baird<br>D.S. Smith |
| Photogrammetric Method and Apparatus | T.J. Blachut<br>A.J. Smialowski |
| Conductivity Measurement Apparatus with means for Comparing Sampled and Reference Voltages | T.M. Dauphinee |

TABLE 2.8 1. II. PATENTS (continued)

| Titles | Inventor(s) |
|---|---|
| Dome Fermentor | M.A. Anderson<br>P.S.S. Dawson<br>W.G.W. Kurz<br>A.E. York |
| High Protein Snack Foods | B.D. Panchuk<br>M. Anderson<br>C.G. Youngs |
| Treatment of Rapeseed Meal | J.M. Bell<br>C.G. Youngs<br>H.R. Sallans |
| Continuous Phased Culturing of Cells | P.S.S. Dawson |
| Yeast Fermentation Producing Glycosides | J.F.T. Spencer<br>A.P. Tulloch<br>P.A.J. Gorin |
| Iron or Copper Compound Catalytic Decomposition of Thioglucosides in Rapeseed | C.G. Youngs<br>H.R. Sallans<br>J.M. Bell |
| Fermentation with Chaetomium to Produce Cochliodinol | D. Brewer<br>W.A. Jerram<br>A. Taylor |
| Panic Latch Tester | G.T. Luke<br>G. MacLean |
| Fluid Settlement Gauge | M. Bozozuk |
| Apparatus for Recording Aggregate Totals of Measurement of Parameters | T.K. VanTuyl |
| Asphalt Shingles | P.J. Sereda |
| Window Construction | G.K. Garden |

2.8 2. and 3. Publications and Reports

The staff of the NRC Laboratories reported the results of their research in approximately 8,400 publications during the period from 1968 to 1975. This figure includes books or contributions to books, papers published in scientific or technical journals, and laboratory reports. The numbers of publications in each of these three categories is presented by year in Table 2.8 2. I.

A report entitled "Titles of Published Papers by the National Research Council Laboratories 1968-1975", is submitted as Exhibit 2. It contains a list of the titles of papers published in the open literature, the names of authors, the journal in which the paper was published, and the year of publication. A companion report, "Titles of Reports by the National Research Council Laboratories 1968-1975", submitted as Exhibit 3, provides a list of technical reports, laboratory memoranda, and testing and calibration reports. Exhibit 4 provides a list of the titles of the 23 publications of the staff of the Canada Institute for Scientific and Technical Information made between 1968 and 1975.

The record of publications of a university researcher is a major factor in the award of research grants. It is estimated from a sampling of research applications that the grantees supported by the Program of Scholarships and Grants in Aid of Research write about 5,000 papers a year.

TABLE 2.8 2. I.

Total Output of

Books, Papers, and Reports Arising from Research Activities

of NRC Laboratories from 1968 - 1975

| Publications: | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975* |
|---|---|---|---|---|---|---|---|---|
| Books or major contributions to books. | 19 | 14 | 9 | 13 | 9 | 30 | 22 | (17) |
| Papers published in scientific and technical journals and conference proceedings. | 705 | 665 | 724 | 760 | 783 | 849 | 857 | (642) |
| Reports | 276 | 293 | 283 | 269 | 294 | 313 | 348 | (203) |
| TOTAL | 1000 | 972 | 1016 | 1042 | 1086 | 1192 | 1227 | (862) |

*Figures in parentheses are incomplete - they are for the first 9 months of 1975.

2.8 4. Conferences, Seminars, and Symposia

Conferences, seminars, and symposia are other means of transferring knowledge and information. In 1973, for example, NRC's Associate Committee on Geotechnical Research sponsored the first national conference held in Canada to consider the technical implications of northern pipeline construction. The conference, held in Ottawa, reviewed the results of Canadian research on northern terrain, with special emphasis on the development of technology for the construction of oil and gas pipelines in northern Canada. The conference attracted more than 500 delegates from Canada, the United States, and the Soviet Union.

The Division of Building Research regularly holds building-science seminars and construction workshops. Two-day seminars, held twice in Ottawa and once in Calgary each year, provide architects and engineers with an understanding of building science. Construction superintendents attended nine workshops held in 1972-73. Members of the staff also give courses to teachers from schools of architecture and institutes of technology. They deliver lectures to small groups of builders and to associations.

The Division of Physics holds annual seminars on such topics as time and frequency, statistics in measurement, and community noise. These seminars are held to solve problems and to identify the needs in a given area.

They are attended by representatives from industry, municipal authorities, and environmental groups.

A Man-Computer Communications Seminar organized by the Division of Electrical Engineering deals with problems in the general area of interactive graphics techniques and applications. This seminar is held biennially, with participants from universities, industry, and federal and provincial governments. In 1973, for example, the seminar attracted 35 authors, with a total participation of 300 people.

In 1973 the National Research Council sponsored a symposium at which a new Canadian learned society was formed - The Canadian Society for Color in Art, Industry, and Science. The society was formed at the initiative of the Division of Physics and a number of Canadian industries interested in color. It provides a useful forum for the discussion of color problems of all kinds and brings together in a single organization artists, psychologists, educators, designers, decorators, engineers, architects, and scientists who have an active interest in color.

The titles of some other conferences, seminars and symposia sponsored by the National Research Council are presented in Table 2.8 4. I.

The National Research Council, through its Program of Scholarships and Grants in Aid of Research, supports research publications and conferences to the extent of approximately $650,000 a year.

TABLE 2.8 4. I. A LIST OF CONFERENCES AND SEMINARS

ORGANIZED OR SPONSORED BY THE NATIONAL RESEARCH COUNCIL

1. Research Seminar on Frost Action in Soils, Ottawa, 1968.
2. Third International Peat Congress, Ottawa, 1968,
3. Third Canadian Conference on Permafrost, Ottawa, 1969.
4. Research Seminar on the Geological Engineering Aspects of Landslides, Ottawa, 1969.
5. Seventh International Conference on Soil Mechanics and Foundation Engineering, Ottawa, 1969.
6. Sixth Conference on Snow and Ice, Ottawa, 1969.
7. Twenty-Second Canadian Soil Mechanics Conference, Ottawa, 1969.
8. Soil Dynamics Research Seminar, Ottawa, 1970.
9. Thirteenth Muskeg Research Conference, Fredericton, 1970.
10. Research Seminar on Construction Problems in Permafrost, Saskatoon, 1971.
11. Active Layer Seminar, Vancouver, 1971.
12. Fourteenth Muskeg Research Conference, Kingston, 1971.
13. Canadian Northern Pipeline Research Conference, Ottawa, 1972.
14. Permafrost Thermal Regime Seminar, Saskatoon, 1972.
15. Seminar on Engineering Evaluation of Mechanical Properties of Soils, Ottawa, 1972.
16. Seminar on Ice Jams, Edmonton, 1973.
17. National Conference on Urban Engineering Terrain Problems, Montreal, 1973.
18. Seminar on Analytical Methods in Soil Mechanics, Vancouver, 1973.
19. Fifteenth Muskeg Research Conference, Edmonton, 1973.

TABLE 2.8 4. I. CONFERENCES AND SEMINARS (continued)

20. Permafrost-Hydrology and Geophysics Symposium, Calgary, 1974.

21. Seminar on Thermal Regime of River Ice, Quebec, 1974.

22. Glacial Till - An Interdisciplinary Conference, Ottawa, 1975.

23. Symposium on Permafrost Geophysics, Waterloo, 1975.

24. Seminar on Failure Criteria for Natural Soils, London, 1975.

25. Sixteenth Muskeg Research Conference, Montreal, 1975.

26. Building Science Seminar on Fire and Design of Buildings, Ottawa and Calgary, 1968.

27. Building Science Seminar on Air Conditioning and the Design of Buildings, Ottawa and Calgary, 1969.

28. Construction Workshop on Wall and Roof Construction, Ottawa, 1969.

29. Construction Workshop on Some Aspects of Winter Construction, Ottawa, 1970.

30. Building Science Seminar on Fire Safety in High Buildings, Ottawa and Calgary, 1970.

31. Construction Workshop on Some Construction Considerations, Saskatoon, Ottawa, Halifax, 1971.

32. Building Science Seminar on Walls, Windows and Roofs, Ottawa and Calgary, 1971.

33. Construction Workshop on Roofing, Insulation, Sealants and Masonry Problems, Ottawa, 1972.

34. Building Science Seminar on Cracks, Movements and Joints in Buildings, Ottawa and Calgary, 1972.

35. Construction Workshop on Walls, Windows and Roofs, Toronto, Montreal, Moncton, London, Winnipeg, Thunder Bay, Regina, Edmonton, Vancouver, 1973.

36. Seminar/Workshop on the Design for Smoke Control in High Buildings, Toronto (twice), Montreal, Halifax, Winnipeg, Edmonton, Calgary, Vancouver, Regina, 1974.

TABLE 2.8 4. I. CONFERENCES AND SEMINARS (continued)

37. Construction Workshop on Walls, Windows and Roofs, Sudbury, Windsor, Sherbrooke, St. John's and Quebec, 1974.

38. Seminar/Workshop on Energy Conservation and Building Design, Toronto (twice), Winnipeg, Montreal, Halifax, Calgary and Vancouver, 1974.

39. Seminar/Workshop on Performance of Membrane Roofing Systems, Toronto (twice), Montreal (twice), Ottawa, Winnipeg, Edmonton, Vancouver and Halifax, 1975.

40. Measurement Seminar on Photometry and Colorimetry, Ottawa, 1970.

41. Measurement Seminar on Electrical Measurements, Ottawa, 1971.

42. Measurement Seminar on Thermometry, Ottawa, 1971.

43. Measurement Seminar on Length and Other Mechanical Measurements, Ottawa, 1972.

44. Measurement Seminar on Noise and the Community - Technical, Planning and Legislative Control, Ottawa, 1973.

45. Measurement Seminar on Time and Frequency, Ottawa, 1973.

46. Measurement Seminar on Statistics, Ottawa, 1973.

47. Measurement Seminar on Mass and Force Measurement, Ottawa, 1974.

48. Measurement Seminar on Photometry and Colorimetry, Ottawa, 1974.

49. Measurement Seminar on Electromagnetic Measurements, Ottawa, 1975.

50. Measurement Seminar on Temperature Measurement, Ottawa, 1975.

51. Second Conference on Surfaces, Ottawa, 1969.

52. Conference on High Voltage Impulse Techniques, University of Toronto, 1971.

53. Biennial National Conference on Man-Computer Communications, Ottawa, 1969, 1971, 1973, 1975.

TABLE 2.8 4. I. CONFERENCES AND SEMINARS (continued)

54. Seminar on Engineering in Health Care, Ottawa, 1973.

55. Seminar on Radiation Biology, Ottawa, 1968.

56. International Symposium on the Identification and Measurement of Environmental Pollutants, Ottawa, 1971.

57. Circumpolar Conference on Northern Ecology, Ottawa, 1975.

2.8 5. Transfer of the World's Scientific and Technical Data

The National Research Council, through the Canada Institute for Scientific and Technical Information, has developed a variety of mechanisms to facilitate the dissemination or transfer within Canada of scientific and technical data produced in other parts of the world. For example, using its extensive collection of international scientific and technical publications, the Institute responds to requests for factual information by lending books, by providing photocopies of papers, and through the retrieval and interpretive skills of its staff.

To supplement these services, the Canada Institute for Scientific and Technical Information has developed computerized techniques which are effective in transferring information. CAN/SDI (Canadian Selective Dissemination of Information) continuously alerts subscribers to the existence of recent papers covering their specific fields of interest. This service, which covers the world's scientific and technical literature (journals, reports, patents, and proceedings of conferences) is at present serving approximately 6,000 users seeking information in the various fields of science, engineering, and medicine. Augmenting this service is the CAN/OLE program (Canadian On-Line Enquiry). Through

34 centres and 160 video terminals located across Canada, this service permits users remote from Ottawa to search the world's scientific and technical literature and in a matter of minutes determine what has been published during the last 5-6 years in all the major fields of science and technology. At present, CAN/OLE is responding to approximately 10,000 searches or enquiries per month. The Canada Institute for Scientific and Technical Information backs up these services by ensuring the availability of copies of all cited papers.

2.8 6. <u>Postdoctorate Fellows, Research Associates, and Visiting Scientists</u>

In 1948 the National Research Council introduced a program of Postdoctorate Fellowships tenable in NRC Laboratories. Fellowship awards were made on the basis of an annual competition. The purpose of these awards was to provide opportunities for promising young scientists to develop their research careers and to broaden their research experience by working on advanced research projects in NRC Laboratories. This program, which was later extended to include other government laboratories, has been highly successful. The program also provided a pool of highly competent young researchers, actively sought for recruitement by universities, industries, and government laboratories. At the same time, the NRC Laboratories benefited

enormously from this flow of bright young talent and the contributions the Postdoctorate Fellows have made to NRC research programs.

With the recent revision of NRC's role and the challenges ahead, the time was opportune to take another step forward and to build on the proven features of the PDF program. In a number of NRC research projects, and this number will undoubtedly increase in future, a degree of continuity is required for the investigator to make a significant contribution. This is a particular feature of many engineering research projects and because of this constraint it has not been possible for Postdoctorate Fellows, whose tenure was restricted to one or two years, to participate fully in such projects. Yet this is a most important objective since such experience is invaluable for young researchers seeking a career in the industrial sector. Additionally, since most universities are now also operating PDF programs, it is deemed desirable that the NRC program should complement and extend existing university programs.

As of April 1, 1975 the earlier program of Postdoctorate Fellowships was terminated and replaced by a new program called NRC Research Associates. As previously, awards are made through an annual competition on the basis of demonstrated ability and promise to perform original research of high quality.

In lieu of a fixed stipend as for the former Postdoctorate Fellowships, Research Associates are offered salaries and staff benefits comparable to those currently available to members of the regular staff of the National Research Council. The initial award is for a period of one year and may be renewed at intervals for a total period of up to five years. Research Associates undertake and participate in advanced research projects of interest to NRC Laboratories.

The numbers of appointments to positions in NRC Laboratories under these programs since 1968 are as follows:

| | | |
|---|---|---|
| Postdoctorate Fellows | 1968-69 | 76 |
| | 1969-70 | 73 |
| | 1970-71 | 54 |
| | 1971-72 | 53 |
| | 1972-73 | 53 |
| | 1973-74 | 53 |
| | 1974-75 | 48 |
| Research Associates | 1975-76 | 61 |

A complementary program is the Visiting Research Scientist Program which is designed to bring into the laboratories high quality researchers from government, industry, and universities in Canada and abroad to engage in cooperative research programs with the laboratory staff. Under this arrangement, the visiting scientist is given a short-term appointment to work in the laboratories (normally for a period of one year or less). The plan is intended to stimulate the research

effort of the organization and to help ensure the vitality of the laboratory by the infusion of new blood and a fresh outlook. The program also provides the visiting scientists with the opportunity to broaden their scientific knowledge or increase their technological skill by working with highly qualified laboratory personnel. This type of direct contact is found to be a successful means of effecting a transfer of technology and maintaining close cooperation between laboratories and institutions. A list of visiting scientists, together with their affiliation and the Division in which they worked, is given in Table 2.8 6. I to illustrate the scope of the program.

TABLE 2.8 6. I A LIST OF VISITING SCIENTISTS

| Name | Affiliation | Division and Year |
|---|---|---|
| V.P. Wasan | National Physical Laboratory New Delhi, India. | Physics, 1967/68 |
| L. Crovini | Instituto di Metrologia, Torino, Italy. | Physics, 1968 |
| A.G. Amaro | CETENAL, Mexico. | Physics, 1968. |
| V.V. Korobkin | Soviet Academy of Sciences, Moscow, Russia. | Physcis, 1968 |
| A. Mesbah | Hospital Physicist, St. John's, Newfoundland. | Physics, 1968 |
| I.H. Munro | University of Manchester, Manchester, U.K. | Physics, 1968/69 |
| B.R. Watts | University of East Anglia, Norwich, England. | Physics, 1969 |
| J. Zara | Bureau National de Metrologie, Paris, France. | Physics, 1969 |
| P. Delajoud | Societe Desgranges et Hout, Paris, France. | Physics, 1969 |
| M. Ya. Schelev | Soviet Academy of Sciences, Moscow, Russia. | Physics, 1969/70 |
| N.R. Isenor | University of Waterloo, | Physics, 1970 |
| J. Fendler | Texas A&M University | Physics, 1971 |
| J. Ducharme | Bureau de Normalization, Quebec, P.Q. | Physics, 1971 |
| B.I.H. Possingham | South Australian Institute of Technology, Adelaide. | Physics, 1971 |
| H. Medicus | Rensselaer Polytechnic Institute, Troy, N.Y. | Physics, 1971 |
| D.C. Walker | University of British Columbia, Vancouver, B.C. | Physics, 1971 |
| R. Madey | Kent State University | Physics, 1968 and 1972 |
| R. Maccillo | Atomic Institute, San Paulo, Brazil. | Physics 1970/72 |

TABLE 2.8 6. I VISITING SCIENTISTS, (continued)

| | | |
|---|---|---|
| A.A. Malyutin | Soviet Academy of Sciences, Moscow, Russia. | Physics, 1971/72 |
| J.P. Compton | National Physical Laboratory, Teddington, U.K. | Physics, 1971/72 |
| L.C. Henrey | Houston Aggregate Corp., Longueuil, P.Q. | Physics 1971/72 |
| J.J. Hill | National Physical Laboratory, Teddington, U.K. | Physics, 1971/62 |
| H. Werle | Kernforschungszentrum Karlsruhe, Germany | Physics, 1972 |
| J.O. Williams | University College of Wales, Aberystwyth, U.K. | Physics, 1972 |
| S. Fukui | Nagaya University, Japan | Physics, 1972 |
| D. Shoenberg | Royal Society Mond Lab., Cambridge, England. | Physics, 1972 |
| Z. Sitek | Warsaw University, Poland. | Physics, 1972 |
| R. Dittman | P.T.B., Berlin, Germany. | Physics, 1972 |
| G.C.S. Woo | University of Waterloo, Waterloo, Ontario. | Physics, 1972 |
| V.A. Sukhoparov | Academy of Sciences, Moscow, Russia. | Physics, 1972/73 |
| S. Zahwi | UAR National Facilities, Cairo. | Physics, 1972/73 |
| E. Litherland | University of Toronto, Toronto, Ontario. | Physics, 1968 and 1973 |
| S. Chandra | Ravishankar University, Raipur, M.P. India. | Physics, 1970, 1971 1973 |
| J.C. Burgess | University of Hawaii, Honolulu, Hawaii. | Physics, 1973 |
| W.N. Charman | University of Manchester, England. | Physics, 1973 |
| A.N. Rubinov | Belorussian Academy of Sciences, Minsk, Russia. | Physics, 1973 |

TABLE 2.8 6. I VISITING SCIENTISTS, (continued)

| | | |
|---|---|---|
| T. Peucker | Simon Fraser University, British Columbia. | Physics, 1974 |
| A.P. Wenger | Institut de Physique Experimentale, Universite de Lausanne, Switzerland. | Physics, 1972/74 |
| P. Kaiser | York University, Toronto | Physics, 1974 |
| R. Serov | Soviet Academy of Sciences, Moscow, Russia. | Physics, 1974 |
| K. Nakagiri | Radio Research Laboratories, Tokyo, Japan | Physics, 1973/74 |
| G.V. Buxton | University of Leeds, England. | Physics, 1974 |
| H. Bluhm | Kernforschungszentrum Karlsruhe, Germany | Physics, 1974 |
| J. Kroh | Technical University Lodz, Poland | Physics, 1974 |
| J.W. Muller | Bureau International des Poids et Mesures, Sevres, France. | Physics, 1974 |
| H. Ferdinande | Rijk universiteit te Gent, Belgium. | Physics, 1974/75 |
| A. Bujakiewicz | Warsaw University | Physics, 1974/75 |
| P. Thorburn | Bedford Institute of Oceanography, Halifax. | Physics, 1975 |
| R.W. Woods | University of Saskatchewan | Physics, 1975 |
| P. Hirsch | Wolfson Professor of Metallurgy, University of Oxford, England. | Physics, 1968 and 1975 |
| W.S. Stiles | Richmond, England. | Physics, 1970 and 1975 |
| D.J. James | University of Hull, Hull, England. | Physics, 1975 |
| N.R..Isenor | University of Waterloo, Waterloo, Ontario. | Physics, 1975 |

TABLE 2.8 6. I VISITING SCIENTISTS, (continued)

| | | |
|---|---|---|
| G. Trudel | Concordia University, Montreal, Quebec. | Physics, 1975 |
| D.A. Armstrong | University of Calgary, Calgary, Alberta. | Physics, 1971 |
| G. Casperian | Physico-Medical Systems, Corp., Montreal, Quebec. | Division of Electrical Engineering (DEE), '75 |
| A.F. Dalley | Royal Canadian Mounted Police, Ottawa, Ont. | DEE, 1974/75 |
| H.G. Wesa | International Atomic Energy, Zambia | DEE, 1975 |
| G.S. Collins | Consultant | DEE, 1972/74 |
| C. Lane | University of British Columbia, Vancouver. | DEE, 1974 |
| M.S. Murthy | Bhabba Atomic Research Centre, Bombay, India. | DEE, 1973/74 |
| S. Chandra | CIDA | DEE, 1973/74 |
| R. Muccillo | Brazil/Canada Scientific Exchange | DEE, 1970/73' |
| R. Prodanuk | SED Systems Ltd., Saskatoon. | DEE, 1973 |
| G. Bourbeau | Algonquin College, Ottawa, Ont. | DEE, 1972 |
| A.M. Kabeel | United Arab Republic | DEE, 1972 |
| N. Kadima | University of Quebec | DEE, 1972 |
| J. Petkivicious | Soviet Academy of Sciences, Moscow, Russia. | DEE, 1972 |
| A. Calcatelli | Institute di Metrologia, Torino, Italy. | DEE, 1971 |
| R. Lantos | Algonquin College, Ottawa, Ontario. | DEE, 1971 |
| I.E. Samson | CIDA | DEE, 1971 |

TABLE 2.8 6. I VISITING SCIENTISTS, (continued)

| | | |
|---|---|---|
| S. Chandra | CIDA | DEE, 1970 |
| G.P. Gopalaraman | CIDA | DEE, 1970 |
| M. Leggett | Queen's University Kingston, Ont. | DEE, 1969/70 |
| I.M.H. Saad | UNESCO, United Arab Republic | DEE, 1969/70 |
| K.R. Srinivasan | CIDA | DEE, 1969/70 |
| B. Wiggins | I.P. Sharp Associates, Ottawa, Ont. | DEE, 1969/70 |
| S. Bond | Alberta Research Council Edmonton, Alberta. | DEE, 1969 |
| C. Watson | CIDA | DEE, 1969 |
| R. Chandra | UNESCO | DEE, 1968 |
| B.L. Credico | RCA Limited | DEE, 1968 |
| D. Edward | CIDA | DEE, 1968 |
| S. Mastoria | University of Waterloo | DEE, 1968 |
| E. Phillip | Algonquin College, Ottawa, Ont. | DEE, 1968 |
| R.S. Yadavalli | University of Toronto, Toronto, Ontario. | DEE, 1968. |
| B.G. Baker | Flinders University, S. Australia. | DEE, 1971/72 |
| G.J. Johnson | University of New South Wales, Kensington, Australia. | DEE, 1972 |
| S. D'Emilio | Instituto Electtrotechnico Nazionale, Torino, Italy. | DEE, 1973 |
| S. Kashyap | University of Manitoba Winnipeg, Man. | DEE, 1973/74 |
| B.K. Sachdeva | Carleton University, Ottawa, Ont. | DEE, 1974 |

TABLE 2.8 6. I VISITING SCIENTISTS, (continued)

| | | |
|---|---|---|
| M.A. Gullen | Carleton University, Ottawa, Ontario. | DEE, 1974/75 |
| O. Einarsson | University of Lund, Sweden | DEE, 1974/75 |
| W.A. Davis | University of Alberta, Edmonton, Alberta. | DEE, 1975 |
| S. Przezdziecki | Institute of Fundamental Technological Research, Warsaw, Poland. | DEE, 1975 |
| L. Spitz | Arctic Institute, Washington | Herzberg Institute of Astrophysics (HIA) 1970/71 |
| J. Andersen | Observatoire de Marseille, France | HIA, 1971/72 |
| B. Nordstrom | Stockholm Observatory, Sweden. | HIA, 1971/72 |
| R. Kar | Algonquin College, Ottawa, Ontario. | HIA, 1972 |
| G. Moreels | NRC/CNRS Exchange, France. | HIA, 1972/73 |
| D.W. Prendergaast | CIDA | HIA, 1973 |
| C.L. Perry | Louisiana State University, U.S.A. | HIA, 1974 |
| J.M. Marlborough | University of Western Ontario. | HIA, 1973/74 |
| A.P. Cowley | University of Michigan | HIA, 1974/75 |
| C.R. Cowley | University of Michigan | HIA, 1974 |
| E. Van Dessel | Observatoire Royal de Belgique | HIA, 1974 |
| P. M. Millman | Consultant | HIA, 1971/75 |
| J.S. Goldstein | University of Virginia | HIA, 1971 |

TABLE 2.8 6. I VISITING SCIENTISTS, (continued)

| | | |
|---|---|---|
| A.D. Thackeray | Radcliffe Observatory, Pretoria, South Africa. | HIA, 1972 |
| Y.L. Chow | University of Waterloo | HIA, 1973/74 |
| A.J. Colussi | University of Buenos Aires, Argentina. | Chemistry, 1972/73 |
| D. Griller | University College London, London, England. | Chemistry, 1973/75 |
| J.P.E. Grolier | Universite de Clermont, | Chemistry, 1972/73 |
| L.D. Hawton | Lakehead University, Thunder Bay, Ontario. | Chemistry, 1971/72 |
| K. Hukuda | Kyushu University, Fukuoka, Japan | Chemistry, 1969/70 |
| M. Jacon | Universite de Paris Paris, France. | Chemistry, 1974 |
| G.P. Johari | University of Gorakhpur, Gorakhpur, India. | Chemistry, 1970/73 |
| S. Karavelas | University of Ioannina, Ioannina, Greece. | Chemistry, 1974 |
| L. Kertesz | Eovos University, Budapest, Hungary. | Chemistry, 1969/70 |
| H.L. Leibenguth | Universite de Strasbourg Strasbourg, France. | Chemistry, 1971 |
| L. Lunazzi | Universita de Bologna, Bologna, Italy. | Chemistry, 1973 |
| B. Maillard | Universite de Bordeaux Talance, France. | Chemistry, 1974/75 |
| H. Ohya | Yokohama National University, Yokohama, Japan. | Chemistry, 1970 and 1974 |
| W.H. Park | Seoul National University, Seoul, Korea | Chemistry, 1970/71 |
| S. Razumovski | National Academy of Sciences, Moscow, Russia. | Chemistry, 1971/72 |

TABLE 2.8 6. I VISITING SCIENTISTS, (continued)

| | | |
|---|---|---|
| J.C. Scaiano, | Universidad Nacional de Rio Cuarto, Cordoba, Argentina. | Chemistry, 1975/76 |
| G. Vergoten | Universite de Paris, Paris, France. | Chemistry, 1974 |
| H. Watanabe | Hokkaido University, Hokkaido, Japan. | Chemistry, 1970/71 |
| G.E. Zaikov | Academy of Sciences, Moscow, Russia. | Chemistry, 1968 |
| D.C. Dybing | U.S. Department of Agriculture, Brookings, S.D. | Prairie Regional Laboratory (PRL), 1968 |
| C. Mills | Marianopolis College, Montreal, Que. | PRL, 1968 |
| V.K. Sood | Forest Research Institute, Dehra Dun, India. | PRL, 1968 |
| F. Constabel | Pharmakognisches Institute der Universitat Bonn, Bonn, W. Germany. | PRL, 1969 |
| W. Keller | | PRL, 1970/72 |
| B.D. Singh | University of Saskatchewan Saskatoon, Sask. | PRL, 1970 |
| G. Pauly | | PRL, 1970 |
| H.J. Grambow | Institut fur Pflanzen-physiologie Ruhr, Universitat Bochum, Germany | PRL, 1971 |
| M.J. Basterrechea | UNESCO | PRL, 1971/72 |
| E. Jaworski | Monsanto Co., St. Louis, Mo. | PRL, 1971 |
| D.G. Davis | USDA, State University Station, Fargo, N. Dakota. | PRL, 1972 |
| C.H. Drennan | University of Alberta | PRL, 1972 |
| R.C. Zimmer | CDA Research Station, Morden, Man. | PRL, 1972 |

TABLE 2.8 6. I VISITING SCIENTISTS, (continued)

| | | |
|---|---|---|
| D. Lane | University of B.C.<br>Vancouver, B.C. | PRL, 1972 |
| J.X. Hartmann | Florida Atlantic University<br>Boca Raton, Florida. | PRL, 1972 |
| A. Oaks | McMaster University,<br>Hamilton, Ont. | PRL, 1972 |
| K.K. Kartha | | PRL, 1972 |
| L. Babb | University of Alberta,<br>Edmonton, Alberta | PRL, 1973 |
| L. Chen | Atlantic Regional Lab.,<br>Halifax, N.S. | PRL, 1973 |
| P.B. Kaufman | University of Colorado,<br>Boulder, Colorado. | PRL, 1973 |
| T. Degenhardt | | PRL, 1973 |
| J.A. Dubois | Station d'Amelioration des<br>Plantes in Gembloux,<br>Belgium. | PRL, 1974/75 |
| D. Dudits | Biological Research Centre<br>Szeged, Hungary. | PRL, 1974 |
| J.D. Bewley | University of Calgary,<br>Calgary, Alta. | PRL, 1974 |
| D.M. Reid | University of Calgary,<br>Calgary, Alta. | PRL, 1974 |
| G. Weber | University of Hamburg,<br>Hamburg, Germany. | PRL, 1975 |
| U.C. Knopf | University of California,<br>Berkeley, California. | PRL, 1975. |
| Dr. Huber | Max-Planck Inst. fur<br>Biochemie, Munich,<br>Germany. | PRL, 1975 |
| Dr. Kool | Utrecht, Holland. | PRL, 1975 |
| E. Afrikian | Institute of Microbiology,<br>Erevan, Azerbiagan, USSR | Biological Sciences,<br>1968. |

TABLE 2.8 6. I VISITING SCIENTISTS, (continued)

| | | |
|---|---|---|
| S. Balk | Rockerfeller University, New York, USA | Biological Sciences 1971/72 |
| L.R. Barran | Health & Welfare, Canada. | Biological Sciences, 1972 |
| B. Blackburn | University of Winnipeg, Winnipeg, Manitoba. | Biological Sciences, 1969/70 |
| K. Boczon | Medical Academy of Poland, Poznan, Poland. | Biological Sciences, |
| G.B. Calleja | University of the Philippines | Biological Sciences, 1974 |
| B. Cannon | Wenner Grens Institute, Stockholm, Sweden. | Biological Sciences, 1973/74 |
| P. Colson | Université de Liege, Belgique. | Biological Sciences, |
| P. Delisle | Universté Laval, Quebec, P.Q. | 1970/71 |
| J.P. Devlin | Pharma Research Institute, Pointe Claire, Que. | Biological Sciences, |
| W. Dudman | CSIRO, Canberra, Australia. | Biological Sciences, 1974 |
| H. Dugas | University of Montreal, Montreal, Que. | Biological Sciences, 1969/70 |
| J.W. Elder | Fairfield University, Connecticut, USA | Biological Sciences, 1974/75 |
| C. Garrigou-Lagrange | Centre de Recherches Paul Pascal, France. | Biological Sciences, 1973/74 |
| M. Gochnauer | Carleton University, Ottawa, Ont. | Biological Sciences, 1975 |
| G. Govil | Tata Institute, Bombay, India | Biological Sciences, 1972 |
| C. Grieco | University of Naples Italy. | Biological Sciences, 1973 |
| F.E. Hruska | University of Manitoba, Winnipeg, Man. | Biological Sciences, 1969. |

TABLE 2.8 6. I VISITING SCIENTISTS, (continued)

| | | |
|---|---|---|
| V.K. Iyer | Carleton University, Ottawa, Ont. | Biological Sciences, 1969. |
| T.W. James | University of California, Los Angeles, USA | Biological Sciences, 1975 |
| H. Johansen | Carleton University, Ottawa, Ont. | Biological Sciences, 1974. |
| Y.K. Kim | Korea University, Seoul, South Korea. | Biological Sciences, 1971/73 |
| R.W. King | Medical Research Council, London, England. | Biological Sciences, 1974 |
| R. Lalonde | Syracuse University, Syracuse, N.Y. | Biological Sciences, 1973 |
| W.S. Lee | Korean Institute of Technology, Seoul. | Biological Sciences, 1971 |
| G.G. Leppard | Environment Canada, Burlington, Ont. | Biological Sciences 1972/75 |
| H.H. Mantsch | Institute of Chemistry, Cluj, Romania. | Biological Sciences, 1971/75 |
| D. Marsh | University of Oxford, England. | Biological Sciences, 1972/73 |
| N.K. Mathur | University of Jodhpur, India. | Biological Sciences, 1973. |
| M.V. Mayneord | Institute of Cancer Research London, England. | Biological Sciences, 1970 |
| J.F. Miner | Dentist, Ottawa, Ont. | Biological Sciences, 1971/72 |
| P. Moyna | University of Montevideo, Paraguay. | Biological Sciences, 1975 |
| M.J. Neal | University of London, England. | Biological Sciences, 1973 |
| S. Ramamoorthy | Ottawa University, Ottawa, Ont. | Biological Sciences, |
| A.D.P. Raoult | Health & Welfare Canada, Ottawa, Ont. | Biological Sciences, 1973/75 |

TABLE 2.8 6. I VISITING SCIENTISTS, (continued)

| | | |
|---|---|---|
| S. Rousseau | Université Laval, Quebec, P.Q. | Biological Sciences, 1971 |
| A. Rowold | Inorganic Chemistry Institute, Munster, Germany. | Biological Sciences, 1975 |
| K. Schaumburg | H.C. Oersted Institute, Copenhagen, Denmark. | Biological Sciences, 1974 |
| T. Schleich | University of California, Santa Cruz, USA | Biological Sciences, 1973 |
| S. Schreier-Muccillo | University of Sao-Paulo, Brazil. | Biological Sciences, 1971/75 |
| W. Sendecki | University of Warsaw, Warsaw, Poland. | Biological Sciences, 1975 |
| S.C. Sharma | St. Francis Xavier University, Nova Scotia. | Biological Sciences, 1973 |
| D. Shugar | University of Warsaw, Academy of Sciences, Poland. | Biological Sciences, 1968 |
| O. Siiman | Clarkson Institute of Technology, Potsdam, NY | Biological Sciences, 1975 |
| S.P. Verma | New England Medical Centre, Boston, USA. | Biological Sciences, |
| A.B. Vilim | Carleton University, Ottawa, Ontario. | Biological Sciences, 1973 |
| G. Wagner | University of Missouri, USA | Biological Sciences, 1973 |
| K.L. Wierzchowski | Academy of Sciences, Warsaw, Poland. | Biological Sciences, 1973 |
| R.H. Wightman | Carleton University, Ottawa, Ont. | Biological Sciences, 1973 |
| M. Zink | University of Saskatchewan | Biological Sciences, 1975 |

2.8 7. Research Teams

The following examples of research teams that have arisen during the period between 1968 and 1975 demonstrate the variety of research that is done by teams in NRC Laboratories and by industrial and university teams that have been supported by the National Research Council. Research teams in universities have been established both by the pooling of resources granted to individual researchers and, more directly, through NRC's Negotiated Development Grants. These grants are intended either to assist the converted research of established teams of researchers or to build new teams.

Research Teams in NRC Laboratories

- During the past few years a research team specializing in plasma science and the applications of high-power lasers has been established and is now directing its attention to research related to controlled nuclear fusion. This research team has been built from the nucleus of a laser and plasma research group that was set up in the early sixties, when it appeared that this field was very promising, both scientifically and technically. The decision to strengthen this research effort was taken for several reasons, including the increasing probability of fusion being developed as a major energy supply by the end of the century, NRC's major role in long-

term research related to energy, and the need for expertise and awareness to monitor and advise the government on the acquisition of fusion technology when it becomes available. The research group will complement the research activities of other groups in universities, federal and provincial agencies, and industry. It will also provide the essential in-house expertise to permit NRC to properly coordinate a national fusion program.

- Scientists of the Atlantic Regional Laboratory have joined researchers from the Nova Scotia Technical College, Dalhousie University, the Nova Scotia Research Foundation, and the Sydney Steel Corporation to form a cooperative research team known as the Atlantic Group for Research in Industrial Metallurgy[1], with emphasis on the steel industry. An important project is the study of the desulphurization of coke and, more specifically, to determine how to increase the amount of sulphur transferred from the solid to the gas phase during the coking of coal.
- The Environmental Secretariat, part of the Division of Biological Sciences, was formed in 1970 and serves the NRC Associate Committee on Scientific

[1]Supported, in part, by the Industrial Research Assistance Program.

Criteria for Environmental Quality, which had been set up following Government approval. NRC was authorized as the agency with a continuing responsibility to prepare and publish scientific criteria for environmental quality and to operate a scientific and technical information service on pollution research. The permanent Secretariat consists of eighteen members, most of whom are professionals, and these scientists serve as secretaries of sub-committees on Pesticides and Related Compounds, Heavy Metals, Air, Water, Biological Phenomena, and Physical Energy Phenomena. The Secretariat examines the most recent scientific information to derive quantitative assessments of the biological hazards resulting from exposure to pollutants. Published findings in the form of monographs provide source material on cause and effect relationships for regulatory bodies at federal, provincial, and municipal levels.

- In the Division of Building Research, a number of specialized research teams have been established to investigate problems unique to the building industry. In 1969, a Geotechnical Section was formed to study geotechnical problems in cold regions. The former Construction, Design and Building Use Sections were amalgamated in 1974 to

form the Design and Use Section. Within this section a team is being developed to carry out investigations on the use of buildings and their facilities. A specialized team is being developed for the study of room acoustics, investigation of noise sources, and the development of methods for improving room acoustics and controlling noise sources. Particular attention is being given to the development of measurement methods and the establishment of criteria. A team within the Building Services Section has been created to study problems concerned with the use and conservation of energy in residential and commercial buildings.

- In 1972, an Ecological Kinetics research group was formed in the Division of Biological Sciences to study ecological systems using quantitative methods. A collaborative study on the fate of persistent pollutants in the Ottawa River has been developed. The Departments of Biology, Civil Engineering, and Geology at the University of Ottawa are involved in this study, which stresses river clearance kinetics as well as mechanisms and rates of transfer of mercury and organochlorine compounds. Studies are being carried out on the uptake, retention, and release of these compounds by plants.

invertebrates, sediments and, particularly, fish. The kinetics of transfer through water and food chains are being determined. A large-scale computer simulation model and detailed sub-models of individual compartments are used as integral parts of these studies to assess the validity of postulated mechanisms, and to study the sensitivity of the total system to changes in various parameters.

- The weak point in underground high voltage transmission cables is the insulation, in which vulnerability to degradation by moisture is increased by the high electrical gradient existing across the insulating material. One type of failure mechanism under investigation by a research team established in the Division of Electrical Engineering is insulation breakdown through the formation of a "water tree". Moisture penetrates the insulation through a very small surface defect and, under the influence of a combination of external pressure and electrical gradient, moves further into the insulation in a branching path until total insulation failure occurs.
- A research team for determining temporal variations in brightness distribution of quasars by long-baseline interferometry has been operating since 1968. Quasars are distant galaxies with very bright central cores whose radio radiation comes mainly

from regions a few light years in diameter. The resolution needed to determine their brightness distribution requires that the radio telescopes have continental and intercontinental separations. Suitable radio telescopes for centimetre wavelength observations are few in number. The telescope at the Algonquin Radio Observatory, operated as a national facility by the Herzberg Institute of Astrophysics, is one of a half dozen in the world. Astronomers of the Herzberg Institute and of the Appleton Laboratories of the Science Research Council, England, utilize the 46 metre telescope at the Algonquin Radio Observatory with a 25 metre telescope at Chilbolton, England, to monitor temporal variations of several quasars. To date a series of 10 experiments have shown significant changes in some quasars and one Seyfert galaxy on the time scale of a few months. Simultaneous cooperative experiments were also undertaken with the National Radio Astronomy Observatory, Greenbank, W. Virginia, the Owens Valley Radio Observatory, California Institute of Technology, the Harvard Radio Observatory, Fort Davis, Texas, and the Max Planck Institute für Radio Astronomie, Bonn, Germany. These observations augmented the results of observations at Chilbolton and Algonquin Park.

In addition, simultaneous cooperative experiments have been made with the Naroc Radio Observatory, Westford, Mass., and the U.S. Naval Observatory, Maryland Point, Maryland, to provide information on masering water-vapour sources.

- In late 1967, a research team was assembled in the Textile Chemistry Section of the Division of Chemistry to work in the area of light-induced degradation of fibres and plastics. The aim was to investigate the chemical and physical changes which occur during exposure of fibres and plastics to light in the presence of oxygen, and to establish the correlation between these changes and the deterioration of mechanical and aesthetic properties. A longer-term objective was to investigate the role of additives in preventing the key changes noted above. The team has involved at any one time up to five professionals with experience in oxidation processes, light-induced changes, and polymer physics and chemistry. Fundamental structural changes leading to the light-induced failure of three commercially important polymers - polypropylene, polyester, and Nomex - have been established. The work has produced over forty publications, patents in several countries on two

basic inventions and it has generated extensive industrial interest. Results obtained have already caused industry to radically review its approach to the development of new additives, and shown how existing stabilizers can be more effective.

<u>Industrial Research Teams Supported by the Industrial Research Assistance Program</u>

- There has been a net increase in R&D staff in more than half of the 285 companies that have been assisted by the Industrial Research Assistance Program. During the last 5 years there has been a significant increase in the proportion of support going to the food industry, and research teams have been established in several large and small food companies where none existed previously. The effect of the Program has also been evident in the electronics industry, where at least 10 small new companies owe their successful development to the existence of research groups supported by the Program.
- The Program was used by Uniroyal Ltd. to establish the chemical research group responsible for the discovery and subsequent development of the novel agricultural fungicide, VITAVAX[1]. This research team continues to provide the company with a steady flow of novel chemicals for evaluation as potentially important agricultural chemicals.

[1]Trademark.

- One of Canada's larger chemical companies has used the Program to maintain a research team which is making outstanding contributions to the pulp and paper industry. Another team assisted by the Program in the same company has concentrated its efforts on water-based resin emulsions which have important environmental advantages. One of Canada's major oil companies is using the Program to maintain research teams working on projects which relate specifically to Canadian crude oils.
- One of Canada's long established shoe manufacturers is using the Program to establish a research team with capability in the utilisation of synthetic materials for footwear manufacture. A major manufacturer of farm equipment has established a research team, with the assistance of the Program, to investigate new concepts in the design of farm machinery. Several agricultural seed growers are using the Program to support research teams concerned with the development of new varieties of corn and grain more suitable for the Canadian environment.

University Research Teams Supported by NRC

- With the aid of NRC funding, a team has been created at Dalhousie University for the study of coastal zone productivity. The team consists of seven staff members from the Department of Biology, with the

close collaboration of one research scientist from NRC's Atlantic Regional Laboratory. The main objective of the team is to discover the relative importance of environmental and genetic factors in determining the productivity of representative plant and animal populations in the coastal zone. A secondary objective is to demonstrate the possibility of selective breeding of improved strains of marine organisms which might be used in aquaculture. The research is currently concentrated on seaweeds, oysters, and mussels.

- A team of seven researchers in the Department of Chemistry, University of Western Ontario are working in the area of photochemistry, the study of chemical reactions caused by light. Photochemistry is expected to play an important role in future developments in the pharmaceutical industry, synthetic fibre manufacture, and in the production of dyestuff and petroleum products. Research will also be conducted in less commercially developed areas. Light sensitive molecules may be used eventually for energy storage and even information storage. Work is being carried out on the application of the flash - ESR technique to model systems of photosynthesis as well as optically excited states and luminescence in solids.

- A team of eight university scientists from the Departments of Mechanical Engineering and Materials Science of McMaster University is working on the development of metalworking production methods to improve efficiency and productivity through coordinated research in metalforming and cutting and machine tool utilization. Research is also expanding into the area of computer aided manufacturing with emphasis on technological numerical programming and manufacturing systems. Contact is maintained with industry to help ensure that the research activities are both scientifically significant and relevant to important industrial problems.
- A group of eight scientists at the University of British Columbia is pursuing a program of research on the ecology of living terrestrial and aquatic systems. The systems under study include plankton, very small mammals, insects and their parasites, and fish. The approach taken to understanding the interaction within the system has been to add a major perturbation and view the resulting reaction. Analysis of the system's reaction to the disturbance leads to a better understanding of the interaction among individuals in the normal state.
- NRC jointly with the Department of Agriculture of the Province of Saskatchewan provided financial support

for the creation of a Crop Development Centre in the Crop Science Department of the University of Saskatchewan. The eight professional staff of the Centre may in themselves be considered as a team working in the crop development area. In addition the staff solicit the collaboration of researchers both from within the university and from other organizations to tackle specific projects of mutual interest. As an example, a Special Crops project to evaluate the adaptation and potential for commercial production in Saskatchewan of an array of crops, other than the small grains, involves four of the professionals of the Crop Development Centre, six members of the academic staff of the University from six different departments, and four researchers from NRC's Prairie Regional Laboratory.

- Fourteen scientists from the Departments of Computer Science and Electrical Engineering at the University of Waterloo are developing a group in computer communications which will be able to assist Canadian industry, business, and governments in their efforts to harness this new technology. The program of the group includes switched communication systems, and network software and performance. The basic and applied research is being undertaken to solve

peculiarly Canadian problems in computer communications and to enable Canada to take a leadership position in some aspects of computer research.

- A team of seven academic staff members in the Department of Chemical Engineering of the University of Sherbrooke is investigating potential practical uses of peat moss, an abundant natural resource in Canada. The work of the team covers the range from fundamental studies of the physical and chemical properties of peat moss to the development of techniques and equipment for specific applications. The most notable success of the team to date is the development, patenting, and licensing of an extremely effective process to eliminate pollutants, specifically dyes and heavy metals, from industrial effluents. The team has also studied the potential use of peat moss as a constituent of building materials, as an absorber of oil and detergents for the clean-up of oil spills, and as a source of activated charcoal. Work is currently proceeding on the properties of peat moss slurries with a view to determining the feasibility of transport by pipeline to improve the economics of peat moss farming.
- A team at Laval University working in the area of cellular regulatory mechanisms has been strengthened

with the assistance of funds from NRC. The team currently consists of a nucleus of five staff members in the Department of Biology with the participation of another five staff members from the Departments of Biology and Biochemistry. The research objective of this group is of a long-term, fundamental nature, namely to acquire an understanding of intracellular regulatory mechanisms which control and influence plant growth. This work eventually will lead to the study and understanding of the more complex intracellular regulatory mechanisms which control cell division in animals.

2.8 8 Research Facilities

The following examples demonstrate the range of unique or valuable research tools, facilities, and processes that have been added to or developed by NRC Laboratories during the period between 1968 and 1975. A list of research tools and facilities purchased by universities with special major installation grants awarded by the National Research Council is presented in Table 2.8 8. I.

Tools, Facilities, and Processes in NRC Laboratories

- An environmental Laboratory has been established in the Division of Building Research. This is used to study a host of building problems including those

TABLE 2.8 8. I. MAJOR INSTALLATION GRANTS

| Title | University | Amounts | |
|---|---|---|---|
| 10 MEV Tandem Accelerator | Université de Montréal | 1964-65 | $ 50,000 |
| | | 1965-66 | $ 226,000 |
| | | 1966-67 | $ 221,000 |
| | | 1967-68 | $ 235,000 |
| | | 1968-69 | $ 183,000 |
| | | | $ 915,000 |
| Marine Sciences Laboratory | Memorial University | 1965-66 | $ 50,000 |
| | | 1966-67 | $ 300,000 |
| | | 1967-68 | $ 287,000 |
| | | | $ 637,250 |
| Astronomical Telescope | University of Western Ontario | 1965-66 | $ 25,000 |
| | | 1966-67 | $ 75,000 |
| | | 1967-68 | $ 117,000 |
| | | 1968-69 | $ 133,000 |
| | | | $ 350,000 |
| Aquatron | Dalhousie University | 1969-70 | $ 500,000 |
| | | 1970-71 | $ 300,000 |
| | | 1971-72 | $ 200,000 |
| | | | $1,000,000 |
| Controlled Environment Greenhouse | University of Alberta | 1968-69 | $ 350,000 |
| | | 1969-70 | $ 50,000 |
| | | | $ 400,000 |
| Hydraulics Equipment | Queen's University | 1967-68 | $ 40,000 |
| | | 1968-69 | $ 64,000 |
| | | | $ 104,000 |
| Sensory Deprivation Laboratory | University of Manitoba | 1967-68 | $ 110,000 |
| 220 MHz NMR Spectrometer | McMaster/Toronto | 1969-70 | $ 222,300 |
| Installation of Seawater, Freshwater and Scientific Laboratory Equipment to Support Research at the Bamfield Marine Station | Western Canadian Universities Marine Biological Society | 1971-72 | $ 250,000 |
| | | | $ 250,000 |
| | | | $ 500,000 |
| Ultra-High Performance Mass Spectrometry Facility | University of British Columbia | 1974-75 | $ 100,000 |
| | | 1975-76 | $ 111,711 |
| | | | $ 211,711 |

posed by high-rise buildings. The primary functions of the laboratory are to provide for research into the effects of environment on building structures and means of controlling interior environment through the proper selection, design, and assembly of building components and mechanical systems. Work carried out includes studies on the characteristics of building enclosures as environmental separators, the heat and moisture transport properties of insulations and other materials, the performance of environmental control systems and equipment, energy requirements for heating and cooling and the quality of environmental conditions in relation to functional requirements. Other building problems studied by the laboratory include damage to outer walls caused by severe condensation and then repeated freezing at upper levels, and the dangers of asphyxiation from smoke swirling up through a building during a fire. The facility also includes a calorimeter room which is used for the study of the effects of solar energy on interior space.

- A new Seaweed Field Station for long-term studies on the application of scientific agriculture to the cultivation of seaweeds has been established by the Atlantic Region Laboratory at Sandy Cove, Nova Scotia.

The station consists of a combined greenhouse and laboratory, and a pumping and filtering house. Marine algae are being grown at the station for studies on the factors affecting their growth and composition, investigation of their cycles, studies of their genetics, and to collect other information needed for a program of breeding and selection. The program makes it possible to bring about a marked improvement in the quality and yield of seaweeds cultivated under controlled conditions.

- A promising alternative process of recovering oil from tar sands has been developed by the Division of Chemistry. This process of spherical agglomeration is a means of separating suspensions of insoluble particles from liquids by adding a suitable bonding agent that causes the particles to stick together and, on agitation, to agglomerate into spheres. The spheres of materials are then easily removed from the liquid. National Research Council scientists have shown that the process is particularly suited to recovering the oil of the Athabasca tar sands. In this application of spherical agglomeration, the tar sands are added to a light kerosene in continuous agitation, the oil allowed to dissolve, and water sprayed into the system. Under these conditions, the minerals and other hydrophilic materials agglomerate

into spheres, a byproduct that is readily separated and can find use as a gravel or fill material in the construction industry. The kerosene solvent can be recovered from the bitumen extract and recycled.

- A Microwave Acoustics Laboratory has been established in the Division of Electrical Engineering which is equipped to produce microwave acoustic devices in the 5 - 1,000 MHz region of the spectrum. Acoustic waves on the surface of a polished piezoelectric substrate have become increasingly important in signal processing applications. The very low velocity ($10^3$m/s) compared to the velocity of light allow miniaturization of components and the planar nature of the device allows easy access to signals and the utilization of many of the processing techniques used in the semiconductor industry. Applications are mainly in the area of filters, pulse compression, bandpass, and band elimination. Television IF and coded filters are two examples. An Optical Processing Laboratory has also been established to study the dynamic electro-, magneto-, and acousto-optical interactions as well as passive techniques in the processing of optical information. The emphasis is in areas connected with the development of planar optical circuits and devices compatible with the needs of future optical communication links.
- At the Prairie Regional Laboratory, an important new

plant-breeding technique has been developed. The technique, involving the culturing of plant cells in a liquid nutrient medium analogous to fermentation of microbes, makes it possible to study plant processes at the cellular level by using populations of cells all of which are engaged in performing the same biochemical functions. The technique may make it possible to fuse cells from two different plants leading to the development of new and more beneficial plant species.

- At the request of Transport Canada and the Department of National Defence, a Flight Recorder Data Playback Centre has been established at the National Aeronautical Establishment. A program has been designed to permit the gradual buildup of an ability to process original digital flight data into a computer-compatible format. Facilities have also been developed to handle all types of cockpit voice recorders, to make recorded conversation more intelligible, and to analyze background noise. Under the agreement setting up the Centre, Transport Canada and the Department of National Defence send in recorders from aircraft involved in accidents or other incidents for dismantling and playback of information.

- In the Division of Electrical Engineering, a number of significant research tools and processes have been developed for the study of surfaces under ultrahigh vacuum. An apparatus combining Auger spectroscopy and reflection high energy electron diffraction has been developed for surface studies. A simple diaphragm gauge has been developed for use in the range 0.1 to 760 Torr. An accommodation pump which is a novel form of vacuum pump suitable for specialized applications was invented and patented. Tunable dye lasers using liquids have been developed for use in fluorescence spectroscopy. Porous silver normally used as a catalyst for the oxidation of ethylene was developed and used as an ultrahigh vacuum cryopump in a new molecular beam apparatus. Vacuum brazing of molybdenum to stainless steel was perfected permitting 1720 glass to be used routinely in laboratory construction.
- A service for Canadian industry is provided by the National Research Council's Manufacturing Technology Centre, established in the Division of Mechanical Engineering in 1969, which maintains an up-to-date capability in high precision machine tool technology. The Centre exists to serve manufacturers having problems in precision tooling and complex mechanical fabrication. If an existing tool fails to do a

particular job, the Centre tries to manufacture and develop alternatives. It also serves as a focus where companies can obtain advice and technical assistance and, on occasion, assistance in production.

- In 1974, a joint NRC/DND research program on the biological effects of electromagnetic radiation was initiated. Although considerable research data are available concerning the biological effects and safety exposure levels of radiation at microwave frequencies, relatively little is known at the lower radio frequencies. As part of the program, construction of a laboratory to study the biological effects of radiation in the frequency spectrum from 1 to 400 MHz is underway. The laboratory will include exposure chambers to permit the measurement of energy absorption in phantoms and humans as well as an assessment of the distribution of the absorbed energy.
- A technique has been developed by the Division of Biological Sciences which offers a unique opportunity to study several aspects of the structure and function of cell membranes. Biological membranes are made up largely of proteins and of fatty materials called lipids. These membranes are vital components of every living cell, one of their tasks being to control the amount and types of material passing into or out of cells or their component organelles. The method

developed allows study of the organization of the component lipids, the motions they undergo, and the polarity of various regions of the structures they form. In addition, it permits study of the way these properties are affected by materials which are transported through membranes as well as by drugs whose site of action may be a membrane. Thus it provides a probe for studying the relevant mechanisms at the molecular level.

- The addition of a 7 million dollar, 30-foot low speed wind tunnel has augmented the research capability of the National Aeronautical Establishment. This is one of the world's largest wind tunnels, and it was built explicitly at the request of the Canadian aerospace industry. It is used to study both aeronautical and non-aeronautical problems, such as, aerodynamic investigations of aircraft, bridges, buildings, and motor vehicles.
- The Division of Mechanical Engineering has developed a new process of rapid, surface-flaw detection in metal bars that involves a multi-phase, modulated radio frequency field rotating around a bar being examined. Results indicate that very high rotational speeds can be attained, making it possible to detect axial flaws in short lengths of rods with the sample travelling through the system at very high speeds.

- An Optical Solar Observatory on the shore of the Ottawa River near Shirley Bay, Ontario, is now fully operational after several years of construction and trials. A part of the Herzberg Institute of Astrophysics, the observatory makes motion picture analyses of rapidly changing fine structure in sunspot regions in an effort to advance the understanding of the fundamental processes leading to sunspot formation and explosive flare events. Sunspot analyses are important in predicting optimum frequencies to use in radio communications. A battery of telescopes pinpoints one or more active solar regions while exposures are made with cine cameras controlled by a mini-computer. The river site was chosen after careful study of several locations because the cooling effect of the river surface on the local air flow produces long periods of stable viewing that are ideal for solar cinematography.
- A 33-metre absorption tube has been constructed and equipped with a system of mirrors so that light can be passed back and forth along the tube as many as 200 times before emerging. In this way long absorption paths, up to 6.6 km, can be obtained. The tube has so far been used with pressures of gas up to 2 atmospheres, but it is planned to extend the

use of the tube for work with higher pressures. The tube has been used for investigating conditions in planetary atmospheres. For example, when the tube was filled with methane at a pressure of 2 atmospheres, and the absorption path length was 6.6 km, the absorption spectrum of the gas in the region of 7500Å revealed some features which coincided exactly with unidentified features in the spectrum of the planet Uranus. Recently the absorption spectrum of the hydrogen isotope HD has been studied and the results obtained have led to a revision of the deuterium/hydrogen ratio in the atmospheres of some of the major planets, e.g. Jupiter.

- A special spectrographic technique for the precise determination of trace impurities in the nobler metals at much lower levels than was otherwise possible has been developed in the Division of Chemistry. This technique was first applied to studies of the unusual effects produced when trace additives are incorporated in very pure metals. Since then, it has found a number of important applications including the examination of ultra-pure metals used in the production of semiconductors and integrated circuit components. Two methods involving this technique have been incorporated

into the Standard Methods of the American Society of Testing Materials. A spark source mass spectrograph was acquired a few years ago to increase the trace analysis capability. This instrument permits the mass spectrographic analysis of solid samples and is capable of the simultaneous determination of all the elements down to the ppb ($10^{-9}$) level. Since it can detect even a fraction of a monolayer it is valuable in the examination of passive surfaces, for example, on metals, stains on mint coinage, and semiconductor materials. A further technique has been developed using x-ray fluorescent spectroscopy to determine traces of a number of toxic elements in water simultaneously down to below the ppb level. Flameless atomic absorption is another technique used and, although it can only determine one element at a time, it is very precise and capable of extreme sensitivity ($10^{-12}$ to $10^{-14}$ g).

- A supersynthesis radio telescope has been installed at the Dominion Radio Astronomical Observatory in Penticton, B.C., which is used to measure the distribution of hydrogen within our galaxy and other galaxies. Knowledge of the distribution of hydrogen, a major constituent of the universe, is essential to understanding the dynamics of galaxies and their internal physical processes. The telescope uses

four 9-metre diameter parabolic antennae on an east-west line; two of which move along a 300-metre precision railway track. Observations made over many nights are combined to form a map with the same fine detail as could be obtained with a giant radio telescope 600 metres in diameter. The Geodetic Survey of Canada, several Canadian contractors and the Department of Electrical Engineering, University of British Columbia, cooperated to build the telescope. For measurements of nebulae of fairly large angular diameter of the order of one to two degrees, the telescope's sensitivity and ability to discern fine detail makes it unsurpassed in the world.

- In the Division of Biological Sciences, an Isolation Pathogen Facility has been built to permit work with pathogenic bacteria to be carried out without risk to people outside the facility. The facility provides secure containment of bacteria in three rooms with increasing negative air pressure. In the event of the failure of both mains power and an emergency generator, the facility is automatically sealed. People who leave the facility take a shower. All materials that leave the facility are first sterilized; aqueous solutions are chlorinated, air is passed through Hepa filters and incinerated, and other materials are sterilized in a double-ended autoclave. A Plant

Growth Facility has also been added which consists of a greenhouse and environmental chambers. The temperature and illumination of the 400 square foot greenhouse may be controlled to maintain growth of a wide variety of temperate and tropical plants throughout the year. The temperature and illumination of the environmental chambers are totally regulated under clock control to provide suitable conditions for the growth of all types of aquatic plants. Another facility is the Ottawa River Ecology Laboratory. This 2,000 square foot laboratory provides continuously-running Ottawa River water throughout the year for experiments with fish and plants.

- The first section of the Optical Shop of the Dominion Astrophysical Observatory (Victoria, B.C.), Herzberg Institute of Astrophysics, was built in 1969 to house most of the grinding machines and tools that had been purchased in preparation for building Canada's 157-inch telescope. When it appeared probable that Canada would join France in building a 3.6 m telescope on Mauna Kea in Hawaii, the National Research Council agreed to add to the building to take the 160-inch grinding machine that had been stored in Vancouver and to include a 100-ft test tower to permit the grinding, polishing, and testing of

the 3.6 m mirror. The building was completed in 1973; nearly a year was spent in preparing the grinding machine for use and in building the wooden tools, and the shaping and polishing of the mirror has fully occupied the five-man staff for the past year. In addition to the large grinding machine there are 60" (extendable to 72") and 40" machines that have been used to shape a new mirror for the 72-inch telescope, and are being used to grind test mirrors for the CFH telescope. There is supplementary equipment for grinding smaller mirrors and for testing them as well as a 28-inch Balzer vacuum chamber that is being used to create highly reflecting surfaces with multi-layer coatings. This optical shop is the best equipped in Canada for production of large mirrors, especially for astronomical telescopes. There are only two optical shops of comparable size in the U.S. and two more in Western Europe. There exists no capacity in Canadian industry for optics of this size.

2.8 9. Impact of Scientific Activities

The results of a research project are often communicated informally to one's colleagues and other researchers before they are presented formally to the scientific community in a published paper or a presentation at a meeting. This same informal system is used to provide

advice and assistance to people in other government departments, in industry, and in universities. This activity constitutes a significant function of the staff of NRC Laboratories. As an example, the Division of Building Research responded in 1975 to more than 800 written enquiries for technical information and its Information Unit alone received more than 600 telephone calls.

Except for confidential reports to NRC, companies that accept support under the Industrial Research Assistance Program are not required to report their technical or commercial accomplishments in detail, but they are required to exploit the results of their research to the benefit of Canada. A recent survey carried out by the Secretariat of the Committee on Industrial Research Assistance covered 399 projects that had been completed between 1 April 1962 and 31 March 1975. The following are some results from the survey:

- Sales or savings were evident in 118 projects. During a five-year period, these 118 projects received grants of $24.6 million and provided known sales or savings of about $96.8 million.
- New Knowledge of potential benefit resulted from 165 projects which were granted $26.8 million. These projects will result in sales or savings in two or three years.

- In summary, 399 projects were supported with grants of $57.9 million and the 300 companies involved spent $86.9 million. The 283 projects that produced sales, savings, or beneficial new knowledge accounted for 89% of the funds granted. Thirty projects that were considered to be complete failures absorbed 3% of the funds granted and the remaining 8% was spread through 86 projects that were consolidated or terminated by the Committee on Industrial Research Assistance for breaches of the "Condition of Grants" and projects which never started.

Research teams created or supported by the Industrial Research Assistance Program comprise about 10% of the industrial R&D in Canada. A large fraction of the people with Ph.D. degrees who are employed in industrial R&D in Canada have at some time been supported by the Industrial Research Assistance Program. In addition to the above specific benefits, there has been a very significant upgrading of the technological and innovative capability of the companies which participated in the Industrial Research Assistance Program.

2.8 10. Other Measures of Research Output

Another indication of research output is provided by the participation of staff in technical working groups, interdepartmental committees, national and international scientific organizations, and on editorial boards of

scientific journals. In 1973 NRC staff served in various capacities in 284 different national and international organizations. To illustrate the scope of this activity, a list of organizations in which NRC staff served in 1973 is presented in Table 2.8. 10. I.

# TABLE 2.8 10. I LIST OF ORGANIZATIONS SERVED BY NRC STAFF[1]

## Organizations in Canada

**Algonquin College of Applied Arts and Technology**
Advisory Committee, Chairman ........
Members ........

**Atlantic Industrial Research Institute**
Advisory Committee for Strontium Research, Member ........
Advisory Committee on Timber Research, Member ........

**Bishop's University**
Advisory Committee to the Faculty of Science, Member ........

**British Columbia Institute of Technology**
Advisory Committee on Building Technology, Member ........

**Carleton University**
Chancellor ........
Board of Governors, Member (ex officio) ........
Member ........
Honorary Adjunct Professors ........
Honorary Professor ........
Honorary Lecturer in Biophysics ........
Sessional Lecturers ........

**Dalhousie University**
Biology Department
Research Associates ........
Department Oceanography, Research Associate ........

**Douglas College**
Fire Science Advisory Committee, Member ........

**Humber College of Applied Arts and Technology**
Advisory Committee, Member ........

**McGill University**
Honorary Lecturer in Biochemistry ........

**Queen's University**
Advisory Council of Engineering, Members ........
Subcommittee on Chimie, Member ........
Visiting Professor ........

**Ryerson Polytechnic Institute**
Advisory Committee, Member ........
Advisory Committee on Architectural Technology, Member ........

**University of Guelph**
Advisory Member, Faculty of Graduate Studies ........

**Université Laval**
Département de géodésie, Professeur invité ........

**University of New Brunswick**
Department of Civil Engineering, Member ........
Electrical Engineering Department, Curriculum Advisory Committee, Member ........
Faculty of Graduate Studies, Honorary Research Associate ........

**Université d'Ottawa**
Senior Lecturer Department of Physiology ........

**University of Saskatchewan**
Division of Control Engineering, Advisory Board Member ...
Saskatchewan Linear Accelerator Advisory Committee, Member ...

**University of Toronto**
Advisory Board to Systems Building Center, Member ........
Department of Surgery, Research Associate ........

**University of Western Ontario**
Faculty of Engineering Science, Honorary Lecturer ........

**Air Industries Association of Canada**
Standards, Materials & Processes Committee, Member

**Alberta Building Officials' Association**
Member ........

**Alberta Hail Studies Project**
Executive Committee, Member

**Arctic Circle**
Past President

**Arctic Institute of North America**
Board of Governors, Member

**Association of Professional Engineers of Nova Scotia**
Certification Committee for Technologists and Technicians, Member ........

**Association of Professional Engineers of Saskatchewan**
Civil Group Councillor ........
Discipline and Enforcement Committee, Member

**Association of Universities and Colleges of Canada (AUCC)**
Canadian Commonwealth Scholarship and Fellowship Committee, Member

**Atlantic Provinces Inter-University Committee on the Sciences**
Animal Care Subcommittee, Member
Biology Subcommittee, Member
APICS Young Scientist Award Panel, Member
Central Committee, Associate Member

**Atomic Energy Control Board**
Safety Committee Bruce Heavy Water Plant, Member
Reactor Safety Advisory Committee
Control Subcommittee, Member
Accelerator Safety Advisory Committee, Member
Water Resources Subcommittee Secretary
Canadian Society of Plant Physiologists, Representative
Youth Science Foundation, Delegate .

**Building Inspectors' Association of B.C.**
Secretary

**Canada Centre for Remote Sensing**
Reflection Spectroscopy Subcommittee

**Canada Grains Council**
Technical Committee, Member

**Canada Committee on Grain Quality**
Secretary
Member
Subcommittee on Oils, Seeds and Special Crops, Chairman

**Canada Committee on Meat (CASCC)**
Secretary

**Canadian Aeronautical and Space Institute**
Publications Committee, Chairman
Associate Editor

**Canadian Association for Laboratory Animal Science**
Board of Directors, Member

**Canadian Association of Geographers**
Executive Committee (1971-74), Councillor

**Canadian Association of Physicists**
Vice-President
Executive Members
Awards Committee, Members

[1]Taken from NRCL-73.

TABLE 2.8 10. I. ORGANIZATIONS SERVED (continued)

*Canadian Association of Physicists*—Continued/Suite
- Awards Committee, Member
- Educational Trust Fund, Trustee
- Membership Committee
- Optical Physics Division, Past Chairman
- Physics Education Division Executive, Immediate Past Chairman
- Plasma Physics Division, Secretary
- Youth Science Foundation, Representative
  - Publication Committee, Director
  - Youth Science News, Editor

**Canadian Association of Radiologists**
- Committee on Standards, Units & Protection, Member

**Canadian Association of University Research Administrators (CAURA)**
- Member

**Canadian Association of Chiefs of Police**
- Member
- Science and Technology Committee, Member

**Canadian Astronomical Society**
- Council Member
- Member
- Meetings Committee, Member

**Canadian Building Officials' Association**
- Executive Committee, Associate Member
- Advisory Council to CSA on Factory Built Homes, Advisors

**Canadian Committee on Acoustics**
- Secretary
- Editor of Newsletter
- Members

**Canadian Committee on Fats and Oils**
- Vice-Chairman

**Canadian Committee on Oceanography**
- Chairman
- Member

**Canadian Construction Association**
- Canadian Joint Committee on Construction Materials(CCA/RAIC), Member
- Education and Training Committee, Member

**Canadian Council on Animal Care**
- NRC Representative

**Canadian Electrical Association**
- Affiliate Member
- Electrical Apparatus Section, Member
- Transmission and Distribution Sections, Member
- Insulation Co-Ordination Committee, Guest Member

**Canadian Forces Fuels and Lubricants Advisory Committee**
- Member

**Canadian Gas Association**
- Steering Committee on Definitions, Member
- Standards Advisory Committee, Member

**Canadian Government Specifications Board**
- Petroleum Committee, Member
- Test Methods Subcommittee, Chairman
  - Members
- Committee on Filtration, Chairman
  - Member

**Canadian High Polymer Forum**
- Chairman

**Canadian Institute of Food, Science and Technology**
- Journal Editorial Board, Member
- Microbiological Data Committee, Member
- Vice President of Institute

*Canadian Institute of Food, Science and Technology*—Continued/Suite
- National Awards Committee, Chairman
- Speakers Bureau, Chairman
- Ottawa Section, Secretary

**Canadian Institute of Guided Ground Transport**
- Council Member
- Technical Committee No. 2, Member

**Canadian Institute of Mining and Metallurgy**
- Computer Applications and Process Control Committee, Secretary

**Canadian Institute of Surveying**
- Committee on Engineering and Mining Surveying, Member
- Committee on Photogrammetry, Members
  - Subcommittee on Air Photo Interpretation, Member
- Ice and Permafrost Working Group, Members

**Canadian Manufacturers' Association**
- R & D Committee, Member

**Canadian Medical and Biological Engineering Society**
- Publications Committee, Member

**Canadian 220 MHz NMR Centre**
- Managing Committee, Member
- User's Committee, Secretary

**Canadian National Institute for the Blind**
- Joint Committee with Association of Universities and Colleges of Canada on Blind University Students, Member

**Canadian Nuclear Association**
- Radioisotope Committee, Member

**Canadian Pulp and Paper Association**
- Noise Committee, Member
- Research Committee, Technical Section, Member
- Subcommittee on Optical Properties, Member

**Canadian Research Management Association**
- Member

**Canadian Roofing Contractors' Association**
- Technical Committee, Member

**Canadian Society for Color**
- President

**Canadian Society for Mechanical Engineering**
- Heat Transfer and Thermodynamics Division, Secretary

**Canadian Society of Microbiologists**
- President
- Member
- Journal Editorial Board, Associate Editor
- Nominating Committee, Chairman
- Morphology and Structure, Vice-Chairman
- Physiological Section, Chairman

**Canadian Society of Plant Physiologists**
- Western Regional Director

**Canadian Society of Soil Science**
- President-Elect

**Canadian Sounding Rocket Planning Group (CSRPG)**
- Chairman

**Canadian Spectroscopy**
- Associate Technical Editor

**Canadian Steel Industries Construction Council**
- Steel Industries Fellowship Committee, Member (ex officio)
  - Members
  - Fellow

**Canadian Surveyor**
- Associate Editor for Photogrammetry
- Editorial Board, Member

**Chemical Institute of Canada**
- National Council, Councillors
- Chairman
- Board of Qualifications Examiners, Chairman
- Credentials Committee, Chairman
  - Member
- Atlantic Section, Past Chairman
- Analytical Chemistry Division, Past Chairman
  - Executive Committee, Member

TABLE 2.8 10. I ORGANIZATIONS SERVED (continued)

*Chemical Institute of Canada*—Continued/Suite
- Macromolecular Science Division, Secretary-Treasurer
  - Executive Committee, Member
- Medicinal Chemistry Division, Past Chairman
- North Saskatchewan Section, Vice Chairman
- Organic Subject Division, Vice-Chairman
- Ottawa Section, Second Vice-Chairman
- Physical Chemistry Division, Chairman
  - Executive Committee, Member
- Committee to Study Communications, Member
- Committee for the Teaching of Analytical Chemistry in Canada, Member

**Chemistry in Canada**
- Editorial Committee

**C.M.H.C. Liaison Committee with O.R.F. on Reuse of Waste Water**
- Member

**Committee on Radiation Hazards from Electronic Equipment**
- Subcommittee on Human Body Hazards from R.F. Fields, Chairman

**Construction Association of Nova Scotia**
- Apprenticeship and Education Committee, Member

**Council of Ontario Universities**
- Advisory Committee on Academic Planning, Consultant

**Defence and Civil Institute of Environmental Medicine**
- Advisor

**EAI 640 Digital Computer Users Group**
- President

**Eastern Canada Regional Accelerator Committee**
- Member

**Ecologie de la zone du nouvel aéroport de Montréal (EZAIM)**
- Comité consultatif technique, Membre

**Electrical Research Association**
- NRC Official Representative

**Government-Industry Steering Committee (Four Atlantic Housing Com Counterparts)**
- Secretary

**Heating, Refrigerating and Air-Conditioning Institute of Canada**
- Technical Services and Standards Committee, Member
- Atlantic Regional Council, Councillor

**Home Builders' Association of Nova Scotia**
- Regional Research Committee, Member
- Special Low-Cost Housing Committee, Member

**Housing and Urban Development Association of Canada (Formerly NH**
- Board of Directors, Member
- Technical Research Committee, Members

**Institute of Particle Physics**
- President
- Vice President
- Member

**ISIS Working Group**
- Member

**L'Institut de recherche de l'Hydro-Québec**
- Commission consultative technique, Membre
- Commission de revue, Membre

**Manitoba Department of Industry and Commerce**
- Building Materials and System Building Committee, Member
- Electrical and Electronic Products Research Committee, Member
- Materials Science Technical Committee, Member
- Construction Technical Committee, Member

**Maritime Lumber Bureau**
- Technical Projects Development Committee, Member

**Medical and Biological Engineering Journal**
- Editorial Board, Member

**Medical Research Council**
- Associate Member

**Meteoritical Society**
- Director, Meteor Section
- Councillor

**Metric Commission**
- Preparatory Commission on Metric Conversion, Construction Industry, Liaison Committee, NRC Representative

**Ministry of Consumer and Commercial Relations (Ontario)**
- Uniform Building Standards Branch, Safety and Technical Services Division,
  - Uniform Building Code-Code Review Committee Advisors
  - Administration Review Committee, Advisors

**Montreal Association for the Blind**
- Board of Directors, Member

**Montreal Society for Paint Technology**
- Member

**National Advisory Committee on Control Surveys and Mapping**
- Working Group on Urban Surveying and Mapping,
  - Chairman
  - Secretary

**National Advisory Committee on Mining and Metallurgical Research**
- Member
- Physical Metallurgy Subcommittee, Member

**National Advisory Committee on Water Resources Research**
- National Sciences Subcommittee, Member

**National Joint Engineering Societies Committee on Student Counselling**
- Member

**Nova Scotia Building Inspectors' Association**
- Education Committee, Members

**Nova Scotia Committee on Concrete Research**
- Member

**Nova Scotia Department of Labour**
- Consultative Committee on Industrial Safety, Member

**Nova Scotian Institute of Science**
- Council Member

**Nova Scotia Voluntary Economic Planning Division**
- Construction Sector Committee, Member

**Oil and Colour Chemists Association**
- Member

**Ontario Electrical League**
- Electric Heating Standards Committee, Member

**Ontario Engineering Advisory Council**
- Member

**Ontario Food Research Committee (OASCC)**
- Member

**Ontario Heart Foundation**
- Past President, Ottawa Chapter

**Ontario Research Foundation**
- A.E.S. Research Project No. 31 (Reverse Osmosis for Electroplating Waste Treatment, Member

**Ontario Veterinary Association**
- Advisory Subcommittee on Standards for Experimental Surgery, Member

**Ottawa Municipal Police and Fire Department**
- Advisor on Questions Related to Radioactive Materials

**Organization for Economic Co-Operation and Development**
- Information Policy Group, Vice-Chairman
- Tunnelling Office (Mines Branch)
  - Advisory Panel, NRC Representative

**Particle Science and Technology Academic Press Series, Advisory Board**
- Member

**Population Biology Committee**
- Convenor

**Roads & Transportation of Canada Project on Road Safety**
- Member

**Royal Architectural Institute of Canada**
- Architectural Research Committee, Member (ex efficio)

**Royal Astronomical Society of Canada**
- Ist Vice-President

TABLE 2.8 10. I ORGANIZATIONS SERVED (continued)

*Royal Astronomical Society of Canada*—Continued/Suite
- Editor
- Ottawa Center, President
- Ottawa Center, Past President
  - Treasurer
  - Councillor

**Royal Society of Canada**
- Associate Honorary Secretary
- Awards Committee, Member
- Committee on International Relations, Member
- Section III, Editor
- Section III, Physics Subject Division, Convenor
  - Microbiology and Biochemistry Subject Division, Convenor

**'Recent Advances in the Analysis of Organic Pollutants', Annual Sympo**
- Board of Directors, Member

**Science Affairs**
- Editorial Board, Member

**SCITEC**
- Council Member
- Standing Committee on Parliamentary Liaison Program, Ottawa Chapter, Chairman

**Simulation Councils, Inc.**
- Eastern Simulation Council, Chairman

**Society for Computer Simulation**
- Secretary and Newsletter Editor

**Society for Experimental Stress Analysis**
- Ottawa Chapter, Chairman

**Society of Automotive Engineers, Aeronautical Division**
- Committee G4
  - Elastic Seals, Member
- Committee G3
  - Aerospace Fittings, Member
- Committee Tech *N*
  - Physical Properties of Hydraulic Fluids
- Committee Tech *O*
  - Aerospace Applications of Fluids, Member
- Committee A6
  - Fluid Power Technologies, Member

**Specification Writers' Association of Canada**
- Committee on Building Sealants, Member
- Committee on a Building-Standards Index, Member
- Toronto Chapter, Member

**Spectroscopy Society of Canada**
- Director
- Director-at-Large
- National Treasurer

**Standards Council of Canada**
- NRC Representative

**E.W.R. Steacie Prize**
- Trustee

**Toronto Construction Association**
- Building Code Committee, Member

**Toronto Home Builders' Association**
- Technical Systems Committee, Member

**TRIUMF**
- Experiments Evaluation Committee, Member

**Underwriters' Laboratories of Canada**
- Fire Council, Observer

**World Federation of Neurology**
- Research Group on Diagnostic Ultrasound in Neurology, Member

TABLE 2.8 10. I ORGANIZATIONS SERVED (continued)

**Acoustical Society of America**
Executive Council, President
Editorial Board, Associate Editor
Member
Committee on Physical Acoustics, Member
Coordinating Committee of Environmental Acoustics, Vice-Chairman
Technical Committee on Architectural Acoustics, Member

**Advances in Corrosion Science and Technology**
International Board of Advisors, Member

**American Astronomical Society**
Member

**American Ceramic Society (Cement Division)**
Trustee
Board of Abstractors, Member

**American Chemical Society**
Board of Abstractors, Member

**American Concrete Institute**
Committee 115 - Research, Member
Executive Sub-Committee, Member
Committee 216 - Fire Resistance and Fire Protection, Member
Committee 318 - Building Code Requirements for Reinforced Concrete, Observer
Committee 348 - Structural Safety, Member
Committee 437 - Strength Evaluation of Existing Concrete Structures, Chairman
Canadian Capital Chapter, President

**American Institute of Aeronautics and Astronautics (AIAA)**
Technical Committee on Ground Testing and Simulation, Member

**American Institute of Physics**
Publications Board, Member

**American National Standards Institute (ANSI)**
Committee on Absorption of Sound in Air, Chairman
Committee C42 - Electrical Definitions, Member
Committee C68 - IEEE Delegate
Committee C100 - Electrical Reference Instruments, Member
Committee S1 - Acoustics, Liaison Member
Committee S2 - Mechanical Shock and Vibration, Liaison Member
Committee S3 - Bio-acoustics, Liaison Member
Working Group S3-37, Earphone Couplers, Member
Committee S3-52, Attenuation of Hearing Protectors, Member
Committee on Microphones, Member

**American Society for Testing and Materials(ASTM)**
Committee D-2 on Petroleum Products, Members

Committee D-9 on Electrical Insulating Materials, Member
Committee D-27 on Electrical Insulating Liquids and Gases, Member
Committee E2 on Spectroscopy, Member
Committee E9 on Fatigue
Subcommittee E09.04 on Apparatus & Test Methods, Member
Subcommittee E09.08 on Cyclic Strain, Member
Subcommittee E09.05 on Aircraft Structural Fatigue Problems, Member
Subcommittee E-24 on Fractography, Member
Committee E20 on Temperature Measurement, Member
Committee E28 on Mechanical Testing, Member
Subcommittee E28.03 Definitions & Elastic Constants, Chairman
Subcommittee E28.01 Calibration, Member
Research and Development Division IX, Chairman
Research and Development Division VI-C, Chairman
Research and Development Division, VII-B-2, Chairman

**American Society of Civil Engineers**
Committee on Performance of Earth-Supported Structures, Member

*American Society of Civil Engineers*—Continued / Suite
Local Qualifications Committee-District 3, Committee 10, Member
Research Council on the Behaviour of Expansive Earth Materials, Associate Member
Research Council on Performance of Full-Scale Structures, Member
Task Committee on Inspection, Member
Task Committee on Wind Forces, Member

**American Society of Civil Engineers and the International Association (Engineering (ASCE-IABSE)**
Joint Committee 'The Planning and Design of Tall Buildings'
Committee No. 5 - Gravity Loads, Member
Committee No. 7 - Wind Loading and Wind Effects, Member
Committee No. 8 - Fire and Blast, Member
Committee No. 10 - Structural Safety and Probabilistic Methods, Member

**American Society of Heating, Refrigerating and Air-Conditioning Engin**
Nominating Committee for 1973-74 officers, Member
Finance Committee, Member
Guide and Data Book Committee
Subcommittee, Handbook of Fundamentals, Member
Research Committee, Chairman
Task Group on Energy Requirements for Heating and Cooling, Member
Technical Committee on Fruits and Vegetables, Member
Technical Committee on Thermal Properties of Foods, Chairman
Member
Technical Committee 1.1 - Thermodynamics and Psychrometrics, Member
Technical Committee 1.2 - Instruments and Measurements, Member
Technical Committee 4.1 - Load Calculation Data Procedures, Member
Technical Committee 4.2 - Weather Data and Design Conditions, Member
Technical Committee 4.3 - Ventilation Requirements and Infiltration, Member
Technical Committee 5.6 - Control of Fire and Smoke, Chairman
Technical Committee 8.7 - Humidifying Equipment, Member

**American Society of Lubrication Engineers**
Industrial Member

**American Vacuum Society**
Journal of Vacuum Science and Technology, Editor
Board of Editors, Member

**Applied Spectroscopy**
Canadian Editorial Representative

**Association of Official Analytical Chemists**
Executive Committee, Member
Editorial Board, Member

**Asphalt Roofing Technical Committee**
Member

**Australian Institute of Physics**
Associate Member

**Biomedical Engineering Society, USA**
Member

**Building Officials' Conference of America**
Members

**Chemical Rubber Company, Cleveland**
'Hospital Engineering Series', Editor-in-Chief

**Chemical Society of Great Britain**
Fellow

**Clay Minerals Society, USA**
Membership Committee, Member

**Coblentz Society for Vibrational Spectroscopy**
Committee on Data Evaluation, Chairman

**Concrete Society, United Kingdom**
Member

**Corrosion Science**
Overseas Editorial Board, Member

**Electrochimica Acta**
Advisory Editorial Board, Member

TABLE 2.8 10. I ORGANIZATIONS SERVED (continued)

**Encyclopedia of Environmental Science and Engineering**
Editorial Advisory Board, Member
**European Polymer Journal**
Honorary Regional Editor
**Gordon Research Conferences**
Committee Members

**Harvard College Observatory**
Honorary Associate
**Illuminating Engineering Research Institute**
Board of Trustees, Member
**Textile Institute, Canadian Section**
Executive Committee Member
**Model Code Standardization Council (formerly Joint Committee on Buil-**
Sr. Member
**NASA Working Groups on Space Shuttle**
Aerothermodynamics and Configurations, Member
**National Academy of Sciences, National Research Council (USA)**
Executive Council, Member
Committee on Hearing Bioacoustics and Biomechanics
Members

Fire Research Committee, Member
Committee on Macromolecular Chemistry, Member
Subcommittee on Porphyrins, Member
Subcommittee on use of Radioactivity Standards, Member
United States Highway Research Board
Committee A2E06 on Basic Research in Concrete, Member
Committee A3E04 on Snow and Ice Control, Member
Committee A2L04 on Frost Action, Chairman
National Cooperative Highway Research Program
Panel 18-2, Member
Topic 3-07, Member
**National Committee on Radiation Protection and Measurements (USA)**
Subcommittee M-1 on Standards and Measurement of Radioactivity for Radiological Use, Member
**National Council on Radiation Protection and Measurements**
Committee on Radioactivity Standardization Procedures, Member
**National Fire Protection Association (USA)**
Committee 56C on Hospitals
Subcommittee on Hyperbaric Chambers, Member
Sectional Committee on the Safe Use of Electro-Medical Equipment in Hospitals, Members

Committee 80A on Exposure Fire Protection, Member
Alternate
Committee 90A on Air Conditioning and Ventilating Systems
Revision Committee, Member
Committee 101 on Safety to Life, Member
Sectional Committee on Detection Devices, Member
Committee on Code Evaluation, Chairman
Committee on Fire Tests, Member
**National Soil Survey Committee (USA)**
Engineering Applications and Interpretation, Member
**New York Academy of Science**
Member
**Optical Society of America**
Editorial Board Applied Optics, Member
Committee on Uniform Color Scales, Member
Interferometry Technical Group, Vice-Chairman
Technical Group Committee, Member
**Quadripartite Navies Information Exchange Program**
Policy Committee, Member
**Review on the Deformation Behaviour of Molecules**
Advisory Board, Member
**Royal Institute of Chemistry of Britain**
Fellow
**SCOPE**
Canadian National Committee, Secretary
Member

**Smithsonian Institution**
Councillor
**Space Shuttle Working Group**
Plasma Physics and Environmental Perturbation Laboratory, Member
**Tissue Culture Association of America**
Committee on Standards for Chemically Defined Media, Chairman
Plant Division, Chairman
**Underwriters Laboratories, USA**
Medical and Dental Equipment Group, Member
**University of Florida**
Distinguished Visiting Professor
**Wyeth Laboratories, Philadelphia**
Consultant

# TABLE 2.8 10. I ORGANIZATIONS SERVED (continued)

**Alliance française**
Direction de Halifax
Troisième Vice-président

**Americas Towing Tank Conference**
Executive Committee
Seakeeping Committee, Chairman
Instrumentation Committee, Chairman

**Bureau international des poids et mesures**
Comité consultatif d'électricité, Membre
Comité consultatif pour les étalons de mesure des radiation ionisantes, Membres
Comité consultatif pour la définition du mètre, Membre
Comité consultatif sur photométrie, Membre
Comité consultatif sur thermométrie, Président du comité
Comité consultatif sur thermométrie, Membre
Comité consultatif des unités, Membre

**Chemical Physics Letters**
Editorial Advisory Board, Members

**Commission internationale de l'éclairage**
Comité national canadien, Président
Secrétaire
Membres
Comité TC 1.2 (Photometry), Président du comité
Comité TC 1.3 (Colorimetry), Président du comité
Comité TC 2.2 (Sources of UV and IR Radiation)
Comite TC 2.3 (Materials in Lighting), Membre
Comité TC 3.2 (Colour Rendering)
Comité TC 4.2 (Daylighting)
Comité éxecutif, Membres
Comité d'action, Membre

**Comité consultatif international des radiocommunications**
Organisation nationale canadienne (CCIR)
Groupe d'étude 2, Président du groupe
Groupe d'étude 7, Président du comité
Secrétaire

**Comité consultatif pour la définition de la seconde(CCDS)**
Délégue canadien

**Comité européan du béton**
Délégué alterne

**Comité international des poids et mesures**
Membre
'Metrologia', Rédacteur

**Commonwealth Advisory Aeronautical Research Council**
Executive Delegate
Canadian National Delegate

*Commonwealth Advisory Aeronautical Research Council*—Continued/Suite
Delegates
Field of Aerodynamics, Coordinator
Field of Human Engineering, Chief Co-ordinator
Field of Operational Problems and Atmospheric Turbulence, Chief Co-ordinator
Field of Propulsion, Co-ordinator
Field of Structures, Coordinator

**Conférence internationale des grands réseaux électriques (CIGRE)**
Comité d'étude No. 33 (Overvoltages and Insulation Coordination), Membre
Working Group on High Voltage Testing Techniques, Membre
Comité d'étude No. 10, Conseiller canadien
Working Party on Outdoor Insulation, Membre

**Fédération internationale des géomètres**
Comité 5(Instruments et Méthods), Délégué national

**Institute of Electrical and Electronics Engineers (IEEE)**
Field Awards Committee, Morris E. Leeds Award Sub-Committee,Member
Committee on Fundamental Electrical Standards, Member
Committee on Instrumentation in Aerospace Simulation Facilities, Member
Group on Instrumentation and Measurement
Administrative Committee, Vice-President
Member
Committee on Low Frequency Instrumentation and Measurement, Members
Publications Coordination Committee, Chairman
Group on Power Systems Instrumentation and Measurements
Administrative Committee, Member
Editorial Committee, Member
RLL Committee, Working Group on Revision of IEEE 118, Master Test Code for Resistance Measurement, Member
Techniques for Dielectric Tests Committee, Member
Working Group on DC, Member
Working Group on Impulse and Switching Surge Testing
Transmission and Distribution Committee, Member
Standards Co-ordinating Subcommittee, Member
Ottawa Section
Group Chapter on Electrical Insulation, Vice-Chairman

**Intergovernmental Maritime Consultative Organization**
Subcommittee on Fire Protection
Ad Hoc Group on Fire, Member

**International Association of Bridge and Structural Engineering**
Permanent Committee, Member

**International Association for Earthquake Engineering**
Canadian National Committee on Earthquake Engineering
Members

**International Association of Geomagnetism and Aeronomy**
Commission VI (Aurora)
Working Group 1 (Morphology), Member
Working Group 2 (Spectroscopy and Excitation), Chairman
Working Group on Radio Aurora, Member

**International Association for Hydraulic Research**
Committee on Ice Problems, Member

**International Association of Microbiological Societies**
Commission on Microbiological Specifications for Foods
Secretary-Treasurer
Editorial Committee, Member
Liaison Committee, Chairman
World Federation for Culture Collection, President

**International Association for Plant Tissue Culture**
National Representative for Canada and Executive Member

**International Association on the Properties of Steam**
Canadian National Committee, Secretary
Member

TABLE 2.8 10. I ORGANIZATIONS SERVED (continued)

**International Astronomical Union**
Commission 10, Members
Commission 14, Members
Commissions 15, 16, Member
Commission 16, Members
Commission 17, Member
Commission 22, Members
Commission 31, Member
Consultant
Commission 34, Member
Commission 40, Members
Commission 44, Member
**International Biological Programme (IBP)**
Canadian Committee, NRC Representative
Canadian Representative
**International Commission on Optics**
Vice President
Canadian National Committee, Member
**International Commission on Radiation Protection**
Committee 4, Member
**International Commission on Radiological Units and Measurements**
Radiation Physics, Technical Area Member
**International Committee for Symposia on Free Radicals**
Secretary
**International Confederation of Thermal Analysis**
Member
**International Conference of Building Officials (ICBO)**
Member
**International Conference on Physics and Chemistry of Ice**
Organizing Committee, Member
**International Council for Building Research Studies and Documentatio**
Board of BUILD Foundation, Member
International Building Classification Committee, Member
SfB Subcommittee, Member
Working Commission (W-14) on Fire Research, Member
Working Group (S-17) on Heating and Ventilating, Member
Working Commission (W-18) on Timber Roof Structures, Member
Working Commission (W-23) on Basic Structural Engineering Requirements for Buildings, Member
Working Commission (W-40) on Heat and Moisture Transport in Building Materials and Construction, Member
Working Commission (W-61) on Joints in External Walls, Member
Working Commission (W-51) on Acoustics, Member
Working Commission (W-52) on Exchange and Dissemination of Information for Practitioners, Member
Working Commission (W-60) on Performance Concept in Building, Member
Working Commission (W-62) on Water Supply and Drainage Inside Buildings, Member
**International Council on Environmental Law**
Member
**International Council of Scientific Unions**
Inter-Union Commission on Spectroscopy, Chairman
IUPAC Member
Committee on Data for Science and Technology (CODATA)
Canadian National Committee, Chairman
Members
Bureau of CODATA, Vice-President
Task Group on Computer Use, Secretary
Task Group on Data for Chemical Kinetics, Member
Task Group on Fundamental Constants, Member
COSPAR
Working Group III B (The Polar Ionosphere), Member
Working Group III C (Dust), Member
Global Atmospheric Research Program (GARP), Secretary
Committee Member
**International Electrotechnical Commission**
Canadian National Committee on
TC-1, Terminology, Chairman
Member
WG101, Fundamental Definitions, Member
TC-3 Graphical Symbols, Chairman
Member
TC-13, Electrical Instruments, Member
TC-25 Units and Symbols, Chairman
Members
WG1, Units and Symbols, Member
TC-27, Member
TC-28 Insulation Coordination, Member
TC-42, Chairman
TC-45, Member
TC-48A Sockets and Accessories, Chairman
TC-56 Reliability, Member
TC-58, Chairman
TC-61 Safety of Electrical Equipment, Member
TC-62, Member
TC-64 Installation of Electrical Equipment, Chairman
TC-65 Automatic Process Control, Member
TC-66 Electronic Instruments, Member
TC-66, Electronic Instruments, Member
**International Federation of Medical and Biological Engineering Societies**
President
**International Hydrological Decade**
Canadian National Committee, Member
Executive Committee, Member
**International Institute of Refrigeration**
Executive Committee, Member
Canadian National Committee
Chairman
Secretary
Member
Commission $A_1$-Low Temperature Physics, Member
Scientific Council, Member
Commission $B_1$-Thermodynamics and Transport Processes
Member
Commission $C_2$, Refrigeration of Perishable Produce, Vice-President
Commission $D_1$, Refrigerated Storage, Member
Commission $D_2$, Refrigerated Transport by Land, Member
Working Party on Frozen Foods, Members
Working Party on Fruit and Vegetable Packing Stations, Members
Commission $E_1$, Air Conditioning, Member
**International Microwave Power Institute**
President
Secretary
**International Phycological Society**
Treasurer
**International Research Group Renardière on Impulse Measuring Systems**
Member
**International Seaweed Symposium**
Advisory Committee, Member
**International Shock Tube Symposia**
Advisory Committee, Member
**International Shipbuilding Progress**
Editorial Committee, Canadian Representative

## TABLE 2.8 10. I ORGANIZATIONS SERVED (continued)

**International Snowmobile Industries Association**
Sub-Committee on Snowmobile Noise, Members

**International Society for Photogrammetry**
Commission I, Member
Congress Program Coordination Committee, Chairman
Vice-Chairman
Commission II, Member

**International Society of Soil Mechanics and Foundation Engineering**
Canadian Section, Secretary
Representative

**International Standards Organization**
Canadian Advisory Committee on ISO/TC6 - Paper, Board and Pulp, Member
Committee TC6/SC2/WG1 Optical Properties, Chairman
Canadian Advisory Committee TC108 - Mechanical Vibration & Shock, Chairman
Canadian Advisory Committee TC22 - Automobiles, Member
Canadian Advisory Committee on TC28 (Petroleum Products), Chairman
Member
Committee TC38/SC1/WG on Colour Measurement, Member
Canadian Advisory Committee TC38/SC17, Member
Canadian Advisory Committee TC38/SC19, Member
CGSB TC38 Advisory Committee, Member

**International Steering Committee on Circumpolar Populations**
Chairman

**International Symposium for the Identification and Measurement of En**
Vice-Chairman

**International Symposium on Snow and Ice**
Canadian Planning Committee, Member
Canadian Program Committee, Member

**International Towing Tank Conference**
Executive Committee, Representative for the Americas

**International Union of Crystallography(I.U.Cr.)**
Canadian National Committee, Secretary
Member
Commission on Crystallographic Computing, Chairman
Commission on Crystallographic Data, Ex-officio Member
Commission on Structure Reports, Members

Single-Crystal Intensity Measurement Project, Local Coordinator
Standing Committee on Apparatus and Standards, Member
'Structure Reports', Metals Section Co-Editor
Inorganic Section Co-Editor
'World Directory of Crystallographers', Sub-Editor for Canada
Working Party on Information Services, Member

**International Union of Forest Research Organizations**
Division V, Member

**International Union of Pure and Applied Biophysics**
Canadian National Committee, Member

**International Union of Pure and Applied Chemistry**
Commission on Molecular Structure and Spectroscopy
Subcommission on Infrared Spectroscopy, Member
Advisory Councillor
Applied Chemistry Division, Fats and Oils Section, Member
Physical Chemistry Division, President
Interdivisional Committee on Machine Documentation in the Chemical Field, Titular Member
National Committee for IUPAC
Royal Society of Canada, Representative

**International Union of Pure and Applied Physics**
Canadian National Committee, Secretary
Member
Commission on Acoustics, Member
Commission on Atomic and Molecular Physics and Spectroscopy, Corresponding Member
Commission on Very Low Temperature Physics, Member

**International Workshops on Biomedical Engineering**
Biomedical Equipment Maintenance Service Programs, Chairman

**Joint Canada-Federal Republic of Germany Working Group on Marine**
Member

**Joint US and Canadian Great Lakes Load Lines Committee**
Member

**Journal of Chemical Thermodynamics**
Editorial Advisory Board

**Journal of Environmental Analytical Chemistry**
Editorial Board

**Journal of Geophysical Research, Space Physics**
Associate Editor

**Journal of Labelled Compounds**
Editorial Advisory Board, Member

**Journal of Macromolecular Science**
Editorial Board, Member
Reviews in Macromolecular Chemistry
Editorial Advisory Board, Member

**Journal of Magnetic Resonance**
Editorial Advisory Board, Member

**Journal of Molecular Spectroscopy**
Editorial Advisory Board, Members

**Journal of Molecular Structures**
Editorial Advisory Board, Member

**Journal of Phycology**
Associate Editor

**Journal of Polymer Science**
Editorial Advisory Board, Member

**Journal of Raman Spectroscopy**
Co-Editor

**Journal of Thermodynamics**
Editorial Advisory Board, Member

**Lipids**
Associate Editor

**North Atlantic Treaty Organization (NATO)**
NATO Science Committee
Subcommittee of National Fellowship Administrators, Member
Advisory Group for Aerospace Research and Development (AGARD)
Canadian National Delegate
Flight Mechanics Panel, Members

Fluid Dynamics Panel, Member
Guidance and Control Panel, Canadian Representative
Propulsion and Energetics Panel, Member
Structures and Materials Panel
Subcommittee, Environmental Data, Canadian Coordinator
Subcommittee, Acoustic Fatigue, Canadian Coordinator
Central Supply Agency, Food and Agriculture Division
Refrigerated Food Storage and Transport, Member

**Organization for Economic Cooperation and Development**
Tunnelling Office Advisory Panel, NRC Representative
Subcommittee of Information Policy Group on Computer Systems, Member

**Pan American Institute of Geography and History (PAIGH)**
Committee on Large Scale and Urban Surveying and Mapping, President
Manual on Urban Surveying and Mapping, Editor
Committee for Manual on Urban Surveying and Mapping, Chairman
Members

**Permanent International Association of Navigation Congresses**
Members

**Plant Science Letters**
Editorial Board, Member

TABLE 2.8 10. I ORGANIZATIONS SERVED (continued)

**Polymer**
Overseas Editor
**Réunion des laboratoires d'essais et de recherches sur les matériaux et**
Membre
Committee on Performance of Mortars and Renderings, Membre
Committee on Pore Size Distribution for Porous Materials, Membre
Committee on Winter Construction, Membre
**Society of Naval Architects and Marine Engineers**
Ottawa Area Chairman
Seakeeping Committee, Chairman
Member
Hull Loading Chairman
Member
Work Group HS-1-1 'Great Lakes Waves', Member
**Spectrochimica Acta**
Editorial Advisory Board, Members

**E.W.R. Steacie Prize**
Board of Trustees, Member
**Supersonic Tunnel Association**
Member
**The Chemical Rubber Co., Cleveland**
'Hospital Engineering' series, Editor in Chief
**Toxicological and Environmental Chemistry Reviews**
Editorial Advisory Board, Member
Co-Editor
**Union radio scientifique internationale (URSI)**
Comité I, Président du comité
Membres

Comité III, Président du comité
Comité V, Vice-président du comité
Working Group on Absolute Calibration of Solar Radio Flux Densities
Comité VI, Membre
Comité national canadien, Secrétaire
**United Nations**
Scientific Committee on the Effects of Atomic Radiation, Delegate of Canada
**Vacuum**
Editorial Board, Foreign Correspondent
**World Council for the Welfare of the Blind**
Subcommittee on Technical Appliances, Member
**World Energy Conference**
Canadian National Committee, Member
**World Health Organization**
Expert Advisory Panel on Radiation, Member
Expert Panel on Food Microbiology and Hygiene, Member

## 2.9 *Projects*

### 2.9 1. List of Projects

Titles of projects that were in progress in the NRC Laboratories and the Scientific and Technical Information Program in 1968 and 1975 are presented in the following list. An "x" shows whether the project was in progress in one or both of these years. Some projects that were begun after 1968 and completed before 1975 are given in the list with the date of completion in parentheses after the title.

The projects are classified primarily by the following activities and sub-activities:

ACTIVITY I. Basic and Exploratory Research in the Natural Sciences and Engineering

Sub-activities

1. Scientific research
2. Engineering research

ACTIVITY II. Research on Long-Term Problems of National Concern

Sub-activities

1. Transportation
2. Energy
3. Food
4. Building and construction

ACTIVITY III. Research in Direct Support of Industrial Innovation and Development

Sub-activities

1. Industrial Research Assistance Program[1]
2. NRCL contract research
3. NRCL non-contract research

[1] This sub-activity is described in sections 2.7 (b)(II) and 2.8.9.

ACTIVITY IV. Research to Provide Technological Support of Social Objectives

Sub-activities

1. Public safety
2. Environment
3. Health
4. Education and training

ACTIVITY V. National Facilities

Sub-activities

1. Scientific research facilities
2. Engineering test facilities
3. Observational facilities

ACTIVITY VI. Research and Services Related to Standards

Sub-activities

1. Primary
2. Engineering
3. Industrial standards and codes

Scientific and Technical Information Program

It may be noted that the sub-activities under which projects are listed are not mutually exclusive.

Within each sub-activity, the projects are arranged by NRC Laboratory Division, the divisions being identified by the following marginal code:

ARL Atlantic Regional Laboratory

BIO Division of Biological Sciences

CHE Division of Chemistry

DBR Division of Builsing Research

DEE Division of Electrical Engineering

DME Division of Mechanical Engineering

HIA Herzberg Institute of Astrophysics

NAE National Aeronautical Establishment

PHY Division of Physics

PRL Prairie Regional Laboratory

## List of Projects, 1968-75

| | | | 1968 | 1975 |
|---|---|---|---|---|
| **I BASIC AND EXPLORATORY RESEARCH IN THE NATURAL SCIENCES AND ENGINEERING** | | | | |
| **I-1** | **Scientific Research** | | | |
| ARL | 1. | Studies employing Infra-Red Spectrophotometry on the molecular structure of crystalline ice and inorganic hydrates, of water and aqueous solutions of acids and bases, and on the hydration of biopolymers. | x | x |
| | 2. | Studies employing nuclear-magnetic resonance spectrometry (1) on the development of methods whereby isotopic tracers may be used to elucidate the structures and biosynthesis of biological substances, (2) to investigate the composition and structures of inorganic materials such as silicates and phosphates, and (3) to determine the role of catalysts and chemical promoters in the Diels-Alder reaction. | x | x |
| | 3. | Studies employing mass spectrometry on phenomena associated with mass and ion kinetic energy, and field desorption with respect to the development of instrumentation and techniques, and their application to the analysis of biological substances, pollutants, and inorganic compounds such as silicates and phosphates. | x | x |
| | 4. | Biosynthesis of antibiotics and toxins by fungi and actinomycetes. | x | x |
| | 5. | Synthesis of aromatic compounds by the Diels-Alder process. | x | x |
| BIO | 6. | Automatic numerical processing of experimental data from continuous recording devices | x | |
| | 7. | Fundamental studies of methodology in multivariate statistical analysis. | x | |
| | 8. | Chemistry of myxin. | x | |
| | 9. | Physical chemistry of enzyme substrate reactions. | x | |
| | 10. | Proteolytic enzymes from myxobacteria. | x | |

| | List of Projects, Activity I-1 (continued) | 1968 | 1975 |
|---|---|---|---|
| BIO | 11. Cell proliferation in rat thymus and bone marrow and the effects on this process of ionizing radiation and various metabolites and hormones. | x | |
| | 12. Correlation of the chemical properties and toxicity of a poison produced by blue-green algae. | x | |
| | 13. Measurement of the amount and velocity of sucrose transolocation by the use of radioactive tracers in higher plants. | x | |
| | 14. Crystal structure of myxin. | x | |
| | 15. Structures of anilides. | x | |
| | 16. Structure of Bence-Jones protein. | x | |
| | 17. Computer simulation of cell proliferation and its change with time. | x | x |
| | 18. Biosynthesis of phorphyrins. | x | x |
| | 19. Deamination of $\alpha$-amino ketones. | x | x |
| | 20. Degradation products of chlorophylls. | x | x |
| | 21. Structures of alkaloids. | x | x |
| | 22. Synthesis of steroids. | x | x |
| | 23. Synthesis of terpenes. | x | x |
| | 24. Conformational changes in nucleic acids. | x | x |
| | 25. Control of protein synthesis in replicating cells. | x | x |
| | 26. Structure and role of ribosomes in the synthesis of cell protein. | x | x |
| | 27. Structure and role of the cell nucleus in cell differentiation. | x | x |
| | 28. Synthesis of nucleic acids. | x | x |
| | 29. Fibrogenesis in cells. | x | x |
| | 30. Structure and function of cell membranes | x | x |

| List of Projects, Activity I-1 (continued) | | 1968 | 1975 |
|---|---|---|---|
| BIO | 31. Maintenance of the NRC bacteria culture collection and associated taxonomic studies. | x | x |
| | 32. Chemical and physical effects of radiations on constituents of living cells. | x | x |
| | 33. Structure of haptoglobin. | x | x |
| | 34. Studies of the physiological adaptation of animals to cold and season: | | |
| | (a) diet and cold resistance; | x | x |
| | (b) the site of non-shivering thermogenesis; | x | x |
| | (c) the role of the sympathetic nervous system in cold exposure and acclimation. | | x |
| | 35. Curve fitting and data extraction, including numerical deconvolution, from experimental results. | | x |
| | 36. Sensitivity analysis and validation of mathematical models. | | x |
| | 37. Development of polymeric reagents for the automation of organic syntheses. | | x |
| | 38. Sequence studies of a viroid. | | x |
| | 39. Standards for calibration of circular dichrometers. | | x |
| | 40. Synthesis of maytansines. | | x |
| | 41. Amino acid homology. | | x |
| | 42. Role of mitochondrial DNA in cell metabolism. | | x |
| | 43. Differential cellular morphogenesis in yeast cells. | | x |
| | 44. Fine structure of cells by electron microscopy. | | x |
| | 45. Mitochondrial biogenesis. | | x |
| | 46. Biochemical and phsyiological studies of the mechanisms of control of normal and malignant cells. | | x |
| | 47. DNA repair mechanisms in yeast. | | x |

| | List of Projects, Activity I-1 (continued) | 1968 | 1975 |
|---|---|---|---|
| BIO | 48. Genetic control of radiation sensitivity. | | x |
| | 49. Comparative studies of lecithins. | | x |
| | 50. Properties of murine myeloma proteins with antibody activity. | | x |
| | 51. Efficiency of conversion of metabolic energy into biomass. | | x |
| | 52. Isolation, purification, and characterization of proteases obtained from wheat and other plant materials, including industrially and clinically useful enzymes such as papain and chymopapain. | | x |
| | 53. Use of absorption and emission spectroscopy to study the photophysical properties and interactions of molecules of biological interests. | | x |
| | 54. Structure and function of metalloproteins, enzyme mechanisms, and interactions between small molecules and proteins by resonance Raman spectroscopy. | | x |
| | 55. Structures of antibiotics. | | x |
| | 56. Structures of enzymes: β-lytic protease. | | x |
| | 57. Structures of nucleosides. | | x |
| | 58. Structures of phosphazenes. | | x |
| | 59. Structures of pyrimidines and their photoproducts. | | x |
| | 60. Structures of steroids. | | x |
| | 61. Structures of substrates of chymotrypsin. | | x |
| | 62. Structures of synthetic analgetics. | | x |
| | 63. Structures of terpenes. | | x |
| CHE | 64. Dielectric and NMR properties of solids. | | x |
| | 65. Gas hydrates. | | x |
| | 66. Spin lattice relaxation. | x | x |
| | 67. Polymerization initiated by organometallic compounds. | | x |

| | | List of Projects, Activity I-1 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| CHE | 68. | Preparation and characterization of special polymers and of block copolymers. | | x |
| | 69. | Nuclear Magnetic Resonance (NMR) spectroscopy. | | x |
| | 70. | Micro structure of polymers. | x | x |
| | 71. | Chemical kinetics at high pressure | | x |
| | 72. | Properties of high pressure phases (dielectric, x-ray, thermodynamic, Raman spectra, etc.). | x | x |
| | 73. | Far infrared spectroscopy. | x | x |
| | 74. | Reaction kinetics. | x | x |
| | 75. | Electron Spin Resonance (ESR) spectroscopy. | | x |
| | 76. | Chain reactions in solution. | | x |
| | 77. | Atomic, free radical and photochemical reactions. | | x |
| | 78. | Photochemistry of petroleum compounds. | x | x |
| | 79. | Electrochemistry of anodic and cathodic behaviour of nickel. | | x |
| | 80. | Kinetics of oxidation of metals. | | x |
| | 81. | Examination of the physical and chemical structure of surfaces and oxide films. | | x |
| | 82. | Electron diffraction and microscopy. | x | x |
| | 83. | Metallography. | x | x |
| | 84. | X-ray emission analysis. | x | x |
| | 85. | Physical chemistry of Lithium-indium alloys. | x | |
| | 86. | Upper atmosphere chemistry. | x | |
| | 87. | Low temperature calorimetry. | x | x |
| | 88. | Physical chemistry of metals. | x | x |
| | 89. | Solid state inorganic chemistry. | | x |
| | 90. | Photo-degradation studies of cellulose. | x | |

| | List of Projects, Activity I-1 (continued) | 1968 | 1975 |
|---|---|---|---|
| CHE 91. | Mechanisms of degradation of fibre-forming macromolecules. | x | x |
| 92. | Degradation of polypropylene fibres. | x | x |
| 93. | Degradation and stabilization of polymers. | | x |
| 94. | Surface studies; electron microscopy. | | x |
| 95. | Thermodynamic properties of liquid mixtures and solutions. | x | x |
| 96. | Electrochemical synthesis of fluorinated deuterio-hydrocarbons. | | x |
| 97. | Electrochemical synthesis of deuterated heterocyclic and aromatic compounds. | | x |
| 98. | ICSU and IUPAC standards program for infrared and Raman spectra of complex organic molecules. | x | x |
| 99. | Development of techniques for automation of analytic spectrophotometry. | x | x |
| 100. | SPIR search program for infrared spectra. | | x |
| 101. | Computer programs for industrial spectroscopy. | x | x |
| 102. | ESR spectra of aromatic radicals in solution. | x | x |
| 103. | Interactions in crystals of paramagnetic radicals. | x | x |
| 104. | Radiative and radiationless transitions. | x | x |
| 105. | Biomathematics and theoretical biology. | | x |
| 106. | Many-body interactions in solids. | x | x |
| 107. | Lattice dynamics of molecular solids. | x | x |
| 108. | Many-particle problems. | x | |
| 109. | Mercury-photosensitized reactions. | x | |
| 110. | Pyrolytic reactions. | x | |
| 111. | Ion and radical heats of formation by monoenergetic electron impact. | x | x |

| List of Projects, Activity I-1 (continued) | | | 1968 | 1975 |
|---|---|---|---|---|
| CHE | 112. | Studies of organic crystals and semiconductors: recombination radiation, photoconductive and photovoltaic effects, and fluorescence. | x | x |
| | 113. | Sensitization of semiconductor surfaces for photovoltaic effects; solar energy conversion. | | x |
| | 114. | New spectroscopic techniques for biologically important materials. | | x |
| | 115. | Clarification of the nature of intra- and inter-molecular forces by means of vibrational spectroscopy. | x | x |
| | 116. | Resonance Raman effect studies. | x | x |
| | 117. | Ultraviolet and infrared spectroscopy. | x | x |
| | 118. | Structural problems in dyes, natural pigments and biologically important molecules. | | x |
| | 119. | Synthesis of labelled organic compounds. | x | x |
| | 120. | Development of new synthetic methods. | x | x |
| | 121. | Free radical reactions of nitrogen compounds: ammonia, diimide, and methyl diimide. | | x |
| | 122. | Reactivity of excited states; primary photo-chemical processes. | x | x |
| DEE | 123. | Effects of ionic outrapment and gas chemisorption on tungsten. | x | x |
| | 124. | Development and use of apparatus for studying molecular diffraction. | x | x |
| | 125. | Studies of photon echoes in solids with lasers. | | x |
| HIA | 126. | Continuing observations of the microwave flux from the sun. | x | x |
| | 127. | Radio observations of the sun with compound interferometer. | x | x |
| | 128. | Studies of fine-scale structure in the solar photosphere and chromosphere (at the Ottawa River Solar Observatory). | | x |

| List of Projects, Activity I-1 (continued) | | 1968 | 1975 |
|---|---|---|---|
| HIA 129. | Observations of variable sources (now on a reduced scale). | x | x |
| 130. | Measurements of diameters of quasars using Long Baseline Interferometer (with the University of Toronto and Queen's University). | x | |
| 131. | Early-type stars: Studies of supergiants, BE stars, H gamma luminosities, stellar rotation. | x | x |
| 132. | Galactic structure: Studies of HII regions, N and S galactic pole stellar distribution, clusters. | x | x |
| 133. | Investigations of peculiar A stars. | x | x |
| 134. | Other stars: Studies of dwarf novae, infrared objects, novae. | x | x |
| 135. | Investigations of late type stars. | | x |
| 136. | High-resolution observations employing the method of lunar occultations. | x | x |
| 137. | Photometric observations of stars and stellar systems. | x | x |
| 138. | Techniques of data analysis: Development of electronic data, acquisition and analysis systems for the Arcturus measuring machine and Cosmos microphotometer. | | x |
| 139. | Microwave spectra of sources in 3CR catalogue. | x | |
| 140. | Microwave observations of planetary nebulae. | x | |
| 141. | Polarization measurements. | x | |
| 142. | Brightness distributions on millisecond of arc scale of quasars and Seyfert Galaxies by Long Baseline Interferometry techniques. | | x |
| 143. | Measurement of rotational lines of interstellar molecules. | | x |
| 144. | Search for new interstellar molecules. | | x |
| 145. | Flux measurements of radio stars. | | x |

| List of Projects, Activity I-1 (continued) | | 1968 | 1975 |
|---|---|---|---|
| HIA 146. | Measurements of radio outbursts from galactic X-ray sources. | | x |
| 147. | Measurements of the recombination lines of hydrogen and heavier atoms. | | x |
| 148. | Mapping the brightness distribution of galactic objects. | | x |
| 149. | Double stars: Studies of Beta Lyrae, Zeta Auriagae stars, massive binaries, X-ray sources, eclipsing binaries, visual binaries, spectroscopic binaries. | x | x |
| 150. | Development of instrumentation for astronomical research: eight-channel photometer, Richardson spectrograph (Mt. Kobau) radial velocity scanner, ITT tube spectrograph, isocon system (UBC and DAO). | | x |
| 151. | Major projects of optical shop: grinding and polishing of 3.6 m mirror, and hindle sphere for testing secondary mirror, Hartmann tests, for the Canada-France-Hawaii Telescope. | | x |
| 152. | Optical design: Design studies of the prime focus and coude spectrographs for the Canada-France-Hawaii Telescope. | | x |
| 153. | Construction and operation of a spectroscopic rotation synthesis radio telescope operating at 1.42 GHz, for mapping extended regions at high angular and spectral resolution. | | x |
| 154. | Rotation synthesis mapping of north polar region at 22 MHz. | | x |
| 155. | Study of radio sources at 22 MHz and 10 MHz (made with instruments which were nearing completion in 1968). | x | x |
| 156. | Search for rapidly varying radio sources at 1.42 GHz. | | x |
| 157. | Search for red-shifted absorption in distant galaxies and quasars. | | x |
| 158. | Studies with the neutral hydrogen line and recombination lines of galactic objects such as supernova remnants, planetary nebulae and high velocity clouds. | x | x |

| | List of Projects, Activity I-1 (continued) | 1968 | 1975 |
|---|---|---|---|
| HIA | 159. Continuing observations of solar emissions. | x | x |
| | 160. Pulsar observations (although no current projects are underway, observations of specialized pulsar phenomena are made from time to time). | | x |
| | 161. Continuing observations-visual, photographic, radar, rocket, balloon, aircraft, -of meteor phenomena. | x | x |
| | 162. Continuing observations - photographic, photometric radar, rocket, aircraft - of aurora phenomena. | x | x |
| | 163. Observation and modelling of magnetospheric phenomena. | | x |
| | 164. Meteor Observation and Recovery Project (MORP) - in the Prairie Provinces. | | x |
| | 165. Rocket measurements during solar eclipses of 1970 and 1972. | | |
| | 166. Infrared airglow research. | x | x |
| | 167. Infrasound generated by meteors and aurora. | | x |
| | 168. Studies of energetic charged particles in the earth's magnetosphere using the Alouette satellites. | x | |
| | 169. Design of experiments for the ISIS satellites. | x | |
| | 170. Magentospheric studies of low and high energy plasmas using the ISIS satellites. | | x |
| | 171. Studies of charged particles associated with auroral events using rocket techniques. | x | x |
| | 172. Monitoring of the cosmic radiation at various stations in central and northern Canada. | x | x |
| | 173. Studies of cosmic ray density gradients in interplanetary space using ground based neutron monitors. | x | |
| | 174. Design and construction of a large area hodoscope to study the galactic streaming of cosmic rays. | | x |
| | 175. Planning studies for future space experiments involving the NASA 'Shuttle' and a proposed 'out-of-the-ecliptic' spacecraft. | | x |

| | | List of Projects, Activity I-1 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| HIA | 176. | Detailed studies, using spectroscopic methods, of collision processes in atoms and molecules. | x | x |
| | 177. | Investigation of electronic spectra of BF, HNF, $H_2$, AlH, HCP and $Mg_2$. | x | |
| | 178. | Collection and assessment, prior to publication, of spectroscopic molecular constants for all known diatomic molecules. | x | x |
| | 179. | A detailed analysis of the glyoxal spectrum using a complex computer program. | x | |
| | 180. | Measurement of the nuclear magnetic moment of praesodymium. | x | |
| | 181. | Two-photon laser spectroscopy to determine vibrational-rotational frequencies with microwave accuracy. | | x |
| | 182. | Laser and microwave double resonance methods of identifying and measuring very weak transitions. | | x |
| | 183. | Laser Stark and laser Zeeman methods of determining precise molecular constants for both stable molecule and short-lived species. | | x |
| | 184. | Studies of the electronic spectra of molecules such as $D_2$, HD, HF, $F_2$, HCl, $N_2H_2$, $Ar_2$. | | x |
| | 185. | Construction of new devices for the excitation of the spectra of molecular ions and the study of ions such as $HF^+$, $H_2O^+$, $NH_2^+$ and $NO^+$. | | x |
| | 186. | Theoretical studies of the breakdown of the Born-Oppenheimer approximation and of improved treatment of the energy levels of non-rigid molecules. | | x |
| | 187. | Electronic spectra of stable molecules. | x | x |
| | 188. | Electronic spectra of free radicals. | x | x |
| | 189. | Effects of electric fields on molecular spectra. | x | x |
| | 190. | Effects of magnetic fields on molecular spectra. | x | x |
| | 191. | Spectra of astrophysical interest. | x | x |
| | 192. | Double photon spectroscopy. | | x |
| | 193. | Saturated absorption spectroscopy. | | x |

| List of Projects, Activity I-1 (continued) | | 1968 | 1975 |
|---|---|---|---|
| NAE 194. | Characteristics of viscous flow on the edge of a spinning disc. | | x |
| 195. | Unsteady aero-ablation studies | x | |
| 196. | Numerical solution for conical bodies in a supersonic stream. | x | |
| 197. | Studies of unsteady pressure on slender wedges and cones in hypersonic flow (completed 1969). | | |
| 198. | Flow field determinations for conical flow situations (completed 1970). | | |
| 199. | Plane inviscid incompressible flow past a lifting aerofoil (completed 1970). | | |
| 200. | Dynamic stability studies on slender bodies (completed 1970). | | |
| 201. | Parametric approximations for compressible laminar boundary layers with mass transfers (completed 1971). | | |
| 202. | Reynolds number effects on aerodynamic performance and high lift systems (completed 1972). | | |
| 203. | Three-dimensional boundary layer flow phenomena (completed 1972). | | |
| 204. | Research on inviscid transonic flow past shockless airfoils (completed 1973). | | |
| 205. | Turbulent boundary layer flow in a three-dimensional wave/boundary layer interaction (completed 1974). | | |
| 206. | Two dimensional transonic flow sutides. | | x |
| 207. | Suppression of spatial waves by distortion of jet velocity profile. | | x |
| 208. | Formulation of a new triangular plate bending element. | x | |
| 209. | Theory of the elastic suspension of a rigid body. | x | |
| 210. | Applications of extended beam theory to flat plates. | x | |

| | | List of Projects, Activity I-1 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| NAE | 211. | Non-linear flutter of a circular cylindrical shell. | x | |
| | 212. | Finite element studies applied to prediction of vibration and dynamic aeroelastic responses (completed 1969). | | |
| | 213. | Finite element theory applications to three-dimensional unsteady supersonic aerodynamics (completed 1969). | | |
| | 214. | Lattice diffusion coefficients for Nb-Ti systems (completed 1970). | | |
| | 215. | Finite element methods of stress analysis applied to shells (completed 1970). | | |
| | 216. | Applications of extended beam theory to flat plates (completed 1970). | | |
| | 217. | Finite element analysis of cylindrical shell panel - Lockheed Aircraft (completed 1970). | | |
| | 218. | Closed-form finite element solutions for plate vibrations (completed 1970). | | |
| | 219. | Free vibration and random response of multi-bay integrally stiffened panels (completed 1971). | | |
| | 220. | Finite element studies of stress concentrations around holes in cylindrical shells - collaboration with Toronto Institute for Aerospace Studies (completed 1971). | | |
| | 221. | Finite element methods applied to problems involving stationary creep (completed 1972). | | |
| | 222. | Oscillations of a shallow elastic catenary (completed 1973). | | |
| | 223. | Non-linear transient dynamic analyses of circular plates (completed 1974). | | |
| | 224. | Behaviour of plates under high speed impact. | | x |
| | 225. | Finite element procedure for plates with curved boundaries. | | x |
| PHY | 226. | The collection and publishing of data on the structure of materials. These data are published under the auspices of the International Union of Crystallography. | x | |

| List of Projects, Activity I-1 (continued) | 1968 | 1975 |
|---|---|---|
| PHY 227. Computer software to allow a rapid collection and reduction of data on defects in metals. | x | |
| 228. An apparatus for very precise measurement of the de Haas-van Alphen effect and its variation with pressure. With this, dilute alloys have been studied and the nature of the Fermi surfaces determined. | x | |
| 229. Experimental and theoretical investigation of mechanical properties of metals and alloys<br>a) work hardening,<br>b) fatigue,<br>c) solution hardening. | | x |
| 230. New, ultra-high-precision Fermi-surface (F.s.) measurement techniques (precisions are 1 in $10^5$ absolute, 1 in $10^6$ relative, representing a $100\times$ improvement over the techniques previously available) allow | | |
| a) determination of F.s. dimensions in pure metals as reference standards (completed for copper, silver and gold); | | x |
| b) experimental confirmation and investigation of previously inaccessible fundamental details of de Haas-van Alphen (dHvA) effect theory; | | x |
| c) study of the effect of alloying on F.s. dimensions, fitting to computer models based on results of (a) and relating the changes to the particular electronic character of the solute. | | x |
| 231. Pressure effects on Fermi surface: New techniques developed in 230 above provide much improved precision over our earlier measurements (complete for Cu, Ag, Au, continuing for other noble metals). | | x |
| 232. Absorption of sound waves in liquids. | x | |
| 233. Studies of acoustic image formation. | x | |
| 234. Josephson effect monitoring of base unit of voltage. | | x |
| 235. Analysis of data on μ-mesonic X-rays from seventeen elements. | x | |
| 236. High energy proton-proton reactions. | x | |

| | List of Projects, Activity I-1 (continued) | 1968 | 1975 |
|---|---|---|---|
| PHY 237. | Study of interactions of heavy nuclei in emulsions. | | x |
| 238. | Muonic atoms | | x |
| 239. | Boson spectroscopy. | | x |
| 240. | Instrumentation for high energy physics. | x | |
| 241. | Measurement of thermodynamic temperatures using gas thermometry. | | x |
| 242. | Transport properties of metals. | | x |
| 243. | Theory of metals. | | x |
| 244. | Trapped ion spectrometry. | x | x |
| 245. | Surface ion and electron spectroscopy. | | x |
| 246. | Thermal conductivity of platinum at high temperature. | x | |
| 247. | Electrical conductivity of ceramic materials at high temperature. | x | |
| 248. | The specific heat of silver-gold alloys at temperatures below 3 K and the influence of nuclear specific heat. | x | |
| 249. | A large computer program which permits the calculations of Fermi surfaces of materials involving rare earth elements. | x | |
| 250. | Study of the effect of the interaction between magnetic impurities and conduction-electron spins on harmonic amplitude and phase in dHvA oscillations as a new tool for the study of magnetic impurities and of their effect on conduction electrons in a metal. | | x |
| 251. | In conjunction with (248) and (250), a study of conduction-electron scattering in various dilute alloys, and correlation of the results with theoretical treatments in which the electronic character of the solute is taken into account. | | x |
| 252. | Study of the electronic structure of intermetallic compounds and ordered alloys; experimentally, using mainly the de Haas-van Alphen effect, and theoretically by means of band structure calculations. | | x |

| List of Projects, Activity I-1 (continued) | 1968 | 1975 |
|---|---|---|
| PHY 253. Calorimetry: Development of automatic measuring systems and minicomputer software. Measurements on noble metals and alloys yielding information on (a) nuclear, electronic, lattice and cluster contributions to specific heat, (b) ordering and clustering effects, (c) phase stability and phase boundaries. | | x |
| 254. Electron microscopy of defect structures in metals and alloys. | | x |
| 255. Computer simulation studies of the structure and behaviour of dislocation cores under stress in metals and alloys and their influence on the plastic behaviour of materials. | | x |
| 256. The study of interactions of dislocations in complex configurations. | | x |
| 257. An investigation of the processes occurring in rare gas discharges and in their afterglows. | x | |
| 258. Development of a method of stabilizing a helium-neon laser. | x | x |
| 259. Investigation of acoustic waves in liquids by means of light scattering. | x | |
| 260. Investigation of the reflectance and other optical properties of semi-conductors. | x | x |
| 261. Frequency measurements in the IR. | | x |
| 262. Improvement of the visual basis of heterochromatic photometry. | | x |
| 263. Theoretical study of color metamerism. | | x |
| 264. Color matching and color discrimination. | | x |
| 265. Studies of fluorescence in alkali halides. | x | |
| 266. Studies of ionic conductivity. | x | |
| 267. Electro-optical effects in molecular crystals. | x | x |
| 268. Fluorescence spectra of anthracence. | x | |
| 269. Optical properties of ionic crystals. | | x |

| List of Projects, Activity I-1 (continued) | | 1968 | 1975 |
|---|---|---|---|
| PHY | 270. Many-body effects in solids. | | x |
| | 271. Development of a method of measuring the radioactivity of $^{125}I$ and $^{22}Na$. | x | |
| | 272. Reactions of alkyl radicals produced by radiation. | x | |
| | 273. A study of ($\alpha$n) and ($\alpha\gamma$) reactions using the positive ion accelerator. | x | x |
| | 274. Radiation chemistry; pulse radiolysis. | | x |
| | 275. Photoneutron and photon total absorption studies. | | x |
| | 276. Study of means of reducing the effects of diffraction on images. | x | |
| PRL | 277. Function and action of cell membranes in relation to activity of polyene antibiotics. | x | |
| | 278. Production of enzymes by fungi. | x | |
| | 279. Enzymic degradation of mannans and glutamic acid. | x | |
| | 280. Preparation of pure enzymes from bacteria. | x | |
| | 281. Structure of microbial polysaccharides. | x | |
| | 282. Biosynthesis of microbial polysaccharides. | x | |
| | 283. Application of computers to cataloguing of information on microbial culture collections. | x | |
| | 284. Hydrogenolysis of carbohydrates. | x | |
| | 285. Polysaccharides as a basis for chemotaxonomy of yeasts. | x | |
| | 286. Metabolism of oxygenated fatty acids in fungi. | x | |
| | 287. Biosynthesis of coumarins. | x | |
| | 288. Biosynthesis of flavonoids. | x | |
| | 289. Production of anthocyanins by potato tubular cells. | x | |
| | 290. Function of cell components in fungi. | x | x |

| | | List of Projects, Activity I-1 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| PRL | 291. | Effects of chemical compounds on cell membranes in fungi. | x | x |
| | 292. | Production of antibiotics by fungi. | x | x |
| | 293. | Chemical structures of metabolic products from fungi other than antibiotics and enzymes. | x | x |
| | 294. | Biosynthesis of antibiotics, toxins, and related compounds. | x | x |
| | 295. | Metabolism and reproduction of Pythium root-rots. | x | x |
| | 296. | Metabolic pathways and products of selected organisms. | x | x |
| | 297. | Ultrastructure studies - electron microscope. | x | x |
| | 298. | Continuous culture of microorganisms. | x | x |
| | 299. | Analysis of volatile oils and terpenes. | x | x |
| | 300. | Chemotaxonomy based on species differences in composition of essential oils. | x | x |
| | 301. | Chemistry of terpenes. | x | x |
| | 302. | Comparisons of culture methods. | x | x |
| | 303. | Isolation, identification, and morphology of new strains and species of fungi. | | x |
| | 304. | Biosynthesis of aspergillic acids and echinulin in fungi. | | x |
| | 305. | Gas-liquid chromatography of amino acids. | | x |
| | 306. | Polysaccharides of Sporothrix schenkii. | | x |
| | 307. | Synchrony of plant cell cultures. | | x |
| I-2 | | Engineering Research | | |
| DBR | 1. | Study of the basic reactions involved in the degradation of plastics. | x | |
| | 2. | The role of microstructure and mineralogical composition of leda clay on its mechanical behaviour. | x | |

| List of Projects, Activity I-2 (continued) | | | 1968 | 1975 |
|---|---|---|---|---|
| DBR | 3. | Ice formation. | x | |
| DEE | 4. | Biotelemetry research. | x | |
| | 5. | Trapped ion spectrometry. | x | |
| | 6. | Accommodation pumping. | x | |
| | 7. | Continuing refinement to instrumentation for the production and measurement of ultrahigh vacuum. | x | x |
| | 8. | Development and use of an apparatus for auger spectroscopy and reflection high energy diffraction studies. | | x |
| | 9. | Development of an apparatus for photo-electron spectroscopy. | | x |
| | 10. | Studies of laser induced resonance fluorescence. | | x |
| | 11. | Studies of dye lasers as tools for fluorescence spectroscopy. | | x |
| | 12. | Theoretical studies in electro-magnetism. | x | x |
| DME | 13. | SIGNAL DETECTION AND PROCESSING | | |
| | | Magnetic Anomaly Detection | x | |
| | | Spectral Density Analysis (completed 1970) | x | |
| | | Fourier Techniques | x | |
| | | Water Wave Measurements (completed 1969) | x | |
| | | Coherency Analysis of Magnetic Field of Reykjanes Ridge | x | |
| | | Clear Air Turbulence (completed 1971) | | |
| | | Low Temperature Effects on Rats (completed 1969) | | |
| | | Digitizing of Analog Data (completed 1969) | | |
| | | Riding Properties of Container Cars (completed 1969) | | |
| | | Evaluation of Inertial Navigation Systems (completed 1971) | | |

| List of Projects, Activity I-2 (continued) | | | 1968 | 1975 |
|---|---|---|---|---|
| DME | 13. | Continued | | |
| | | Turbulence Above and Below Plant Canopy (completed 1972) | | |
| | | Pipeline Electronic Pig Data Reduction (completed 1974) | | |
| | | Determination of Bridge Piers Displacement (completed 1973) | | |
| | | Determination of Transport Damage to Steel Pipe (completed 1974) | | |
| | 14. | NATURAL GAS PIPELINE SYSTEMS | | |
| | | Pumping Station Models | | x |
| | | Parallel Operation Studies (completed 1972) | | |
| | | Digital Control Design for Compressors in Parallel (completed 1974) | | |
| | | Combined Reciprocating and Centrifugal Pumping Stations (completed 1971) | | |
| | | Optimization of Operation of Multi-unit Pumping Stations | | x |
| | | British Gas at Fergus Pumping Station Model (completed 1974) | | |
| | 15. | SHIP MACHINERY AND CONTROL SYSTEM ANALYSIS | | |
| | | Evaluation of Proposed Design for DDH-280 Destroyer | | x |
| | | Model Support for Maneuvering Trials of DDH-280 (completed 1972) | | |
| | | Design Changes to DDH-280 Resulting from Model Predictions Supported by Ship Trials (completed 1973) | | |
| | | SKL-1 Sumbersible Study (completed 1974) | | |
| | 16. | SATELLITE CONTROL STUDIES | | |
| | | Mill Village Tracking Station Control | | x |
| | | Feasibility Study of a CRC Synchronous Satellite System (completed 1971) | | |
| | | Attitude Control Design Study for Synchronous Satellite (completed 1973) | | |
| | | Study of Problems Involving Flexible Solar Arrays on Synchronous Satellite (completed 1973) | | |
| | 17. | NUCLEAR POWER GENERATING STATION MODELS | | |
| | | Study of Operator Training Requirements (completed 1974) | | |

| List of Projects, Activity I-2 (continued) | | | 1968 | 1975 |
|---|---|---|---|---|
| DME | 17. | Continued | | |
| | | Dynamic Performance Model of a Twin Spool Variable Geometry Turbofan Engine | | x |
| | | Propulsion Controls Study for Twin Engine Helicopter | | x |
| | | Engine Health Monitoring Techniques | | x |
| | 18. | AIRCRAFT PERFORMANCE ANALYSIS | | |
| | | Three-Degree Freedom Study (completed 1970) | | |
| | | STOL aircraft Take-off and Landing Study (completed 1972) | | |
| | | Full Six-Degree of Freedom STOL Aircraft Model (completed 1973) | | |
| | | Fuel Estimates for a Vectored Thrust VTOL Airliner (completed 1974) | | |
| | 19. | VEHICLE DYNAMICS | | |
| | | Railway Vehicle Dynamics | | x |
| | | Magnetically Levitated and Guided (MAGLEV) Urban Transit Vehicle Dynamics | | x |
| | 20. | STUDY OF STRUCTURES | | |
| | | Effect of Earthquakes, Shocks and Blasts (completed 1971) | | |
| | | Damping of Wing-Induced Vibrations | | x |
| | 21. | MATERIALS HANDLING AND SCHEDULING STUDIES | | |
| | | Noranda Copper Smelter | | x |
| | | Stelco Bof Shop (completed 1974) | | |
| | | Quebec Iron and Titanium Smelter | | x |
| | | General Abrasives SIC Shop | | x |
| | 22. | INDUSTRIAL ENGINEERING APPLICATIONS | | |
| | | Machine Interference in Wire Weaving (completed 1971) | | |
| | 23. | IMPROVEMENT OF COMPUTING FACILITY | | |
| | | Digital Plotting Capability (completed 1972) | | |
| | | Graphic Input to Digital and Analog Computers | x | |
| | | Disk Operating System (completed 1969) | | |
| | | Character Printing Interface (completed 1969) | | |
| | | Curve Fitting (completed 1969) | | |

| | | List of Projects, Activity I-2 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| DME | 23. | Continued | | |
| | | Memory Overlay | | x |
| | | Function Generation | | x |
| | 24. | COMPUTATIONAL METHODS FOR OPTIMIZATION PROBLEMS | | |
| | | Optimal Control Problems | x | |
| | | Multi-Dimensional Optimization Problems | | x |
| | 25. | ELECTRICAL POWER SYSTEMS | | |
| | | Steam Power Plant Dynamics and Control (completed 1973) | | |
| | | Pickering Nuclear Power Station Dynamics and Control (completed 1972) | | |
| | | Study of Wake-Induced Galloping of Transmission Lines (completed 1973) | | |
| | | Operator Training Requirements for Nuclear Power Stations (completed 1974) | | |
| | | Gas/Liquid Dynamics of a Heavy Water Plant (completed 1974) | | |
| | 26. | FREE-PISTON ENGINE APPLICATIONS | | |
| | | Gas Generator Free Turbine Engine | x | |
| | | Free Piston Gasifier (completed 1969) | | |
| | | Free-Piston-Activated Hydraulic Pump (completed 1972) | | |
| | | Free-Piston-Activated Electric Generator | | x |
| | | Two-Stroke Engine Inlet Design (completed 1970) | | |
| | | Matching of Turbochargers to Piston Engines (completed 1972) | | |
| | 27. | GAS TURBINE PERFORMANCE | | |
| | | General Model Development (completed 1972) | | |
| | | Performance Estimates for a Rotating Stator Compressor (completed 1972) | | |
| | 28. | SYSTEMS THEORY | | |
| | | Decoupling of State Feedback (completed 1969) | | |
| | | Compensator for Multivariable Systems (completed 1970) | | |
| | | Self-Oscillation in On/Off Systems (completed 1972) | | |
| | | Linear Control System Design Package (completed 1974) | | |

| | | List of Projects, Activity I-2 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| DME | 29. | NUMERICAL METHODS | | |
| | | Two-Point Boundary Value Problems (completed 1969) | | |
| | | Partial Differential Equations (completed 1973) | | |
| | | Approximating Functions on Discrete Sets (completed 1971) | | |
| | | Simulation of Flow in Natural Rivers (completed 1973) | | |
| | | Splines for Interpolation (completed 1973) | | |
| | | Stiff Differential Equations (completed 1974) | | |
| | | Interpolation in Two and Three Variables | | x |
| | | Investigation of the Possible Influence of Fresh Water Outflow on Climate (completed 1969) | | |
| | | Investigation of the Properties and Economics of Large Information Systems | x | |
| NAE | 30. | Development of high resolution airborne magnetometry. | x | |
| | 31. | Vertical gradient compensator for magnetometry. | x | |
| | 32. | Design of new submarine magnetic anomaly detector. | x | |
| | 33. | Development of airborne infra-red scanner system. | x | |
| | 34. | Aeromagnetic reconnaissance of Northern Canada (1969). | | |
| | 35. | Magnetic detector systems for ASW (completed 1970). | | |
| | 36. | Infra-red techniques for aerial survey, MOT, DFF (completed 1970). | | |
| | 37. | STOL aircraft characteristics in landing approach -Cornell Aeronautical Laboratory (completed 1971). | | |
| | 38. | Development of new aeromagnetic techniques, EMR (completed 1971). | | |
| | 39. | AN/ASQ-501 magnetometer assessment at various magnetic latitudes (completed 1971). | | |
| | 40. | Studies in magnetic anomaly detection, DRB (completed 1972). | | |

| | List of Projects, Activity I-2 (continued) | 1968 | 1975 |
|---|---|---|---|
| NAE | 41. Aeromagnetic detection (completed 1972). | | |
| | 42. Airborne remote sensing of magnetic phenomena. | | x |
| | 43. Airborne simulation techniques for V/STOL control system requirements (completed 1974). | | |
| | 44. Lateral-directional stability derivatives for a helicopter (completed 1974). | | |
| | 45. Ultrasonic determination of bulk modulus of fluids. | x | |
| | 46. Construction of 1,000 ft./sec. bird impact simulator. | x | |
| | 47. Research on high temperature alloy protective coatings. | x | |
| | 48. Optimization of properties of composite materials. | x | x |
| | 49. Fatigue of maraging steels. | x | |
| | 50. Stress intensity factors for a progressing crack. | x | |
| | 51. Vibration of a curved fan blade. | x | |
| | 52. Transmission matrices for the vibrations of tapered rods. | x | |
| | 53. Response of structures to high intensity noise | x | |
| | 54. Vibration analysis of dish antenna model (completed 1969). | | |
| | 55. Structural responses to acoustic fatigue (completed 1970). | | |
| | 56. Correlation of pressure fluctuations over structure in the near field noise of a choked jet (screech cycle)(completed 1970). | | |
| | 57. Protective coatings for refractory metals and super alloys (completed 1970). | | |
| | 58. Residual stress analysis by X-ray diffraction methods (completed 1970). | | |
| | 59. Interferometric measurements of strains in aluminum alloy sheets (completed 1970). | | |

| List of Projects, Activity I-2 (continued) | | | 1968 | 1975 |
|---|---|---|---|---|
| NAE | 60. | Finite element analysis of a shell structure - Ecole Polytechnique (completed 1971). | | |
| | 61. | Fatigue problems of CF-104 wing, DND (completed 1971). | | |
| | 62. | Investigation of compacted powder superalloys (completed 1971). | | |
| | 63. | Oxidation resistance of high temperature protective coatings on nickel base alloys (completed 1971). | | |
| | 64. | Powder metallurgy - evaluation of compacted alloys with UACL (completed 1972). | | |
| | 65. | Finite element methods applied to large deformation of plates and shallow shells (completed 1972). | | |
| | 66. | Analysis of folded plate structures (completed 1972). | | |
| | 67. | Isostatic hot-pressing of nickel-base superalloys, with United Aircraft of Canada Limited (completed 1973). | | |
| | 68. | Finite element modelling of flat and curved stiffened panels (completed 1973). | | |
| | 69. | Compacted powder superalloy program. | | x |
| | 70. | Study of the elastic response of a remote manipulator arm. | | x |
| | 71. | Stability of derivatives for bodies of revolution in a supersonic flow. | x | |
| | 72. | Effect of viscosity on stability derivatives. | x | |
| | 73. | Parametric approximations for boundary layers with suction or injection. | x | |
| | 74. | Propagation of blast waves in hypersonic nozzles. | x | |
| | 75. | Angle of attack probe for Black Brant sounding rockets. | x | |
| | 76. | Aerodynamics of spinning mortar shell. | x | |

| List of Projects, Activity I-2 (continued) | | | 1968 | 1975 |
|---|---|---|---|---|
| NAE | 77. | Separated flow over long slender bodies of revolution. | x | |
| | 78. | Low temperature ablation in helium hypersonic wind tunnel (completed 1969). | | |
| | 79. | Half cone pressure field, and application to side-mounted intakes (completed 1970). | | |
| | 80. | Subsonic wall-interference effects in a perforated wall wind tunnel (completed 1970). | | |
| | 81. | Theoretical methods of aerofoil design for super-critical transonic conditions (completed 1970). | | |
| | 82. | Turbulent boundary layers at high Reynolds numbers (completed 1971). | | |
| | 83. | Molecular laser development (completed 1971). | | |
| | 84. | Transonic and supercritical airfoil projects (completed 1972). | | |
| | 85. | Participation in US shuttle spacecraft program (completed 1972). | | |
| | 86. | Theoretical and experimental two-dimensional transonic flow studies (completed 1974). | | |
| | 87. | Vortex wakes of an externally blown jet flap (completed 1974). | | |
| | 88. | High Reynolds number pipe flow investigation. | | x |
| | 89. | Three-dimensional wind tunnel wall interference effects. | | x |
| | 90. | Turbulent boundary layer in a three-dimensional shock wave/boundary layer interaction. | | x |
| PHY | 91. | Study of measurements of absolute spectral sensitivity and non-linearity of photoreceivers, including coordinating new international comparison. | x | |
| PRL | 92. | Oxygen transfer and metabolism in yeasts. | x | x |

| | | | 1968 | 1975 |
|---|---|---|---|---|
| II | RESEARCH ON LONG-TERM PROBLEMS OF NATIONAL CONCERN | | | |
| II-1 | Transportation | | | |
| DBR | 1. | Evaluation of long-term performance of coated fuel drums for use in the North. | x | |
| CHE | 2. | Oxidation of iron. | x | x |
| | 3. | Oxidation of nickel. | x | x |
| | 4. | Electrochemistry of corrosion. | x | x |
| DEE | 5. | TV Frame storage and retrieval. | | x |
| | 6. | Graphic techniques for man-computer interaction. | | x |
| | 7. | Interactive graphics in modelling, planning and decision making. | | x |
| | 8. | Wind speed and direction telemetry - National Parks Branch. | x | |
| | 9. | Split-beam microwave position fixing system. | x | |
| | 10. | Canal radar for navigation in confined quarters. | x | |
| | 11. | Tone burst ranging system. | x | |
| | 12. | Precipitation in radar and propagation. | x | x |
| | 13. | Information classification, storage and retrieval. | | x |
| DME | 14. | Locomotive diesel engine studies - use of Canadian crude oils. Also fuel additives for smoke and pollution control. | x | |
| | 15. | Heavy air cushion transporter studies in support of forest, mining and hydro industries. | | x |
| | 16. | Development of aircraft hydraulic fluids for year-round Arctic use. | | x |
| | 17. | Automotive gear oils for winter use in the colder areas of Canada such as Northern Alberta, Yukon and Northwest Territories. | | x |

| List of Projects, Activity II-1 (continued) | | 1968 | 1975 |
|---|---|---|---|
| DME | 18. Urban car development. | x | |
| | 19. Consideration of the force/displacement/time relationships of typical draft gears under controlled impact conditions and development of criteria for the performance rating of draft gears. | x | |
| | 20. Application of train simulation to the evaluation of modifications in a typical train to improve longitudinal shock characteristics. Computer study and road tests to investigate build-up for forces behind strings of standard and of hydraulically cushioned cars. | x | x |
| | 21. A frame for squeezing railway cars longitudinally, as required for A.A.R. certification. It is used in car testing. | x | x |
| | 22. Construction of new forms of rail environment recorder and their evaluation during controlled impact tests. Analysis of records from field service. | x | |
| | 23. Development of temperature-measuring techniques for control of heating and cooling of continuously welded rail during installation. | x | |
| | 24. Load divider for newsprint car (completed 1974). | | |
| | 25. Impact tests to determine the effectiveness of particular vehicle "tie downs" for heavy vehicles on a railway flat car. | x | x |
| | 26. Study to improve the curving performance of rail car trucks. | | x |
| | 27. Provision of instrumentation and technical assistance to the LRC consortium for tests on a locomotive and car carried out at the High Speed Ground Test Center, Pueblo, Colorado, U.S.A. (completed 1974). | | |
| | 28. Provision of instruments and assistance to Canadian railroads in the study of the operation of a freight car with an "interbogie connection" (completed 1974). | | |
| | 29. Evaluation of flight test performance of prototype 7-channel recorder used for recording of atmospheric gust data. Modification to improve altitude sensitivity at operating altitude (completed 1970). | | |

| | | List of Projects, Activity II-1 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| DME | 30. | Consideration of the existing noise problem at a large Canadian airport and possible developments of the problem associated with projected airport extension. Collaboration with Ministry of Transport on equipment and standards. | x | x |
| | 31. | Development of a capacitative non-contacting precise multi-purpose distance device for immediate application to model wave amplitude measurements, a differential pressure transducer, to be suitable for use at moored depths up to 60 ft. and a solid state step type wave staff sensor. | x | x |
| | 32. | Development of an accelerometer with radio link for deep water wave measurements using free floating buoy. Calibration trials have been conducted in Lake Ontario. | | x |
| | 33. | An instrument developed to measure and record the RMS value of ship vertical acceleration taken over a five minute period. The mean period of the acceleration variations taken over the same interval is displayed. The instrument includes circuitry to correct for the effects of ship's list. | | x |
| | 34. | Development of mounting arrangement that provides an oil damped pendulous support for an acceleration transducer to filter most errors of ship motion that are not in the vertical plane (completed 1974). | | |
| | 35. | Completion of an analogue tide control system together with an analogue data system for the partial model of St. Lawrence, permitting the latter to be calibrated and the model control system performance to be evaluated. Manufacture and assembly of an integrated computerized digital data logging and control system for the entire model (completed 1969). | | |
| | 36. | Fuel spray evaporation. | | x |
| | 37. | Laboratory evaluation of snowmobile engine oils (completed 1973). | | |

| | | List of Projects, Activity II-1 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| DME | 38. | Aviation fuel handling. | | x |
| | 39. | Acceleration Level Counter; Laboratory tests and arrangements made for a field test in an aircraft. Installation at Abbotsford, B.C. for fatigue studies of aircraft used in the spruce bud-worm spraying program. | | x |
| | 40. | A method for the automatic counting of passengers on individual vehicles has been devised, and evaluation of prototype system is being made. | | x |
| | 41. | Aircraft Icing and De-icing | | |
| | | a) A variety of de-icing experiments have been done in the low speed icing wind tunnel on the following: | | |
| | | aircraft windshields | x | |
| | | helicopter engine inlet | x | |
| | | b) Investigations have been carried out on failure of pitot tubes in icing, ice crystal and snow conditions in the high speed icing tunnel. | x | |
| | | c) Anti-icing and de-icing experiments have been conducted on helicopters in the helicopter icing spray rig. | x | x |
| | | d) A research programme on the detection of icing on board helicopter has been conducted. An instrument has been developed based on a dynamic principle. Licence arrangements for manufacture and production have been completed. | | x |
| | | e) A rate of icing instrument based on the helicopter dynamic ice detector has been developed in co-operation with a Canadian industry. | | x |
| | 42. | Icing of Ships at Sea | | |
| | | a) Experiments have been conducted on icing of sections representative of ship spars, booms and masts under conditions simulating ship icing. | x | |
| | | b) Equipment has been set up to determine the adhesive strength of ice to various substrates in order to evaluate various icephobic surfaces. | x | x |

| | | List of projects, Activity II-1 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| DME | 42. | c) In co-operation with MOT, icing questionnaires are distributed to ships' masters on the east coast each winter. From the returns statistical data is being accumulated on the incidence and the severity of ship icing. | | x |
| | 43. | Railway Climatic Problems | | |
| | | a) In central traffic control regions the automatic operation of track switches is essential. The problem of failure due to ice or snow is under investigation. | x | x |
| | | b) Ingestion of snow in locomotive air intake during winter is under investigation by simulation in the cold chamber. | x | |
| | | c) Continuous welded rail must be anchored at a suitable temperature if it is not to fail in subsequent service. Experiments are being conducted on means of cooling the continuous welded rail during the laying process. | x | |
| | | d) A research project on the thermal protection of track switches against snow failure has resulted in development of a pulse jet powered combustion heater for remote area application. Following co-operative field testing with the CPR, arrangements have been completed for manufacture by a Montreal firm. | | x |
| | | e) A field evaluation project has been conducted with the CNR on a novel protection system for railway switch failure resulting from snow. Patent action has been taken on a horizontal air curtain designed to prevent snow from depositing on switches. A manufacturing licence has been arranged with an Ottawa firm for production. | | x |
| | | f) A project has been conducted on development of a railway switch that is not subject to failure from ice and snow. Laboratory tests on a prototype have been completed and field trials started in late 1975. | | x |
| | | g) An investigation into the failure of locomotive sanding equipment at below freezing temperatures has been started. | | x |

| List of Projects, Activity II-1 (continued) | | 1968 | 1975 |
|---|---|---|---|
| DME | 44. Climatic Testing | | |
| | a) Engine and vehicle cold starting tests were carried out at low temperature. | x | x |
| | b) The performance of various engineering equipment was investigated at low temperatures. | x | x |
| | 45. V/STOL aircraft powerplant system studies. | x | |
| | 46. Free piston engine studies. | x | |
| | 47. Diesel engine studies. | x | |
| | 48. Axial compressor studies (completed 1974). | | |
| | 49. In-flight thrust meter for jet engines. | | x |
| | 50. Heavy air cushion transporter studies for the logging, mining and hydro industries. | | x |
| | 51. St. Lawrence River shipping and harbour study. | x | |
| | 52. Other harbour studies (Churchill, Manitoba; Miramichi Channel, N.B.; Port-aux-Basques, Nfld., Gabaras Bay, N.S.). | x | |
| | 53. Wave climate studies. | x | |
| | 54. Diesel engine oil and filter change periods. | | x |
| | 55. Automotive gear oils. | | x |
| | 56. Investigation of the effect of low-intensity microwave radiation on the behaviour of birds on the ground and in the air, to determine the practicability of using microwave radiation for dispersing birds on airfields and from flight path of an aircraft (completed 1972). | | |
| | 57. Design information for fast surface ships. | | x |
| | 58. Monopod oil rig. | | x |
| | 59. Yacht technology for Canadian ship designers and builders. | | x |

| | List of Projects, Activity II-1 (continued) | 1968 | 1975 |
|---|---|---|---|
| DME | 60. Moored and head seas seakeeping program on a drillship model for Canadian company | | x |
| | 61. B.C. car ferry. | | x |
| | 62. Hydrofoil design. | | x |
| | 63. Steering devices for large tankers. | | x |
| | 64. Arctic ship design and development. | x | x |
| | 65. Seakeeping qualities of ships. | x | x |
| | 66. Oceanographic towed body systems. | | x |
| | 67. Calibration of a series of dynamometer couplers using the equipment set up for the static longitudinal compression testing of freight cars. | | x |
| | 68. Construction of a number of transducers for the measurement of the forces exerted by a granular lading on freight car end walls (completed 1974). | | |
| | 69. General discussions with the Canadian railways, of the track hunting problem. The formulation of a shared research program. Assistance to the CPR in the preparation and instrumentation of a caboose to be used for field measurements. | | x |
| | 70. Design and development of a force transducer for the measurement of tread and flange forces (completed 1972). | | |
| | 71. Design and construction of a test rig adaptable to an existing centrifuge, to study scale effects in tracked vehicles (completed 1970). | | |
| | 72. Design of railway car roller test rig. | | x |
| | 73. Provision of instrumentation and technical assistance to Canadian railways in measuring truck (bogie) stiffness, locomotive tractive effort and tunnel heating effects (completed 1972). | | |

| | | List of Projects, Activity II-1 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| DME | 74. | Provision of a force measuring brake shoe and other technical assistance to Canadian railways in measuring locomotive tractive effort, adhesion and brake effectiveness. | | x |
| | 75. | Provision of instrumentation and technical assistance to Canadian railways in measuring rail bridge structure and vibration deflections. | | x |
| | 76. | Provision of instrumentation and technical assistance to Canadian railways in measuring natural frequencies of rolling stock and track structure. | | x |
| | 77. | Provision of instrumentation and technical assistance to Canadian railways in measuring rail-axle misalignment for various truck types in field tests on moving cars. | | x |
| | 78. | Instrumentation and assistance to a Canadian steel company in monitoring the performance of a dunnage arrangement for large pipes on flatcars. | | x |
| | 79. | Preparation of components for installation in new rail car test building (weigh scale and vibration equipment). | | x |
| NAE | 80. | Low altitude turbulence over hilly terrain. | x | |
| | 81. | Development of a flow vane for high speed aircraft. | x | |
| | 82. | Investigation of atmospheric turbulence (mountain wave and storm). | x | x |
| | 83. | Investigation of flying qualities and control system requirements applicable to V/STOL aircraft. | x | x |
| | 84. | Trials of NRC radar altimeter in Guatemala. | x | |
| | 85. | Stability of Avian gyroplane. | x | |
| | 86. | Stratospheric turbulence measurements (completed 1969). | | |
| | 87. | Dynamic instability studies of Avian 2/180 gyroplane (completed 1969). | | |

| List of Projects, Activity II-1 (continued) | | | 1968 | 1975 |
|---|---|---|---|---|
| NAE | 88. | Simulation DHC-7 STOL airliner (completed 1969). | | |
| | 89. | Atmospheric turbulence effects on aircraft in and near jet streams (completed 1970). | | |
| | 90. | Studies of high intensity vortex wakes behind large aircraft (completed 1970). | | |
| | 91. | Variable-stability aircraft as airborne simulators (completed 1972). | | |
| | 92. | Evaluation of aircraft navigation using VLF communications stations (completed 1973). | | |
| | 93. | Abbott Laboratories - aircraft calibration procedures. | | x |
| | 94. | Aircraft operational flight loading. | x | |
| | 95. | Automobile flow control theory. | x | |
| | 96. | Investigation of an automobile telefactoring simulator. | x | |
| | 97. | Fatigue resistance under a low altitude aircraft load spectrum. | x | |
| | 98. | Aircraft response to flight turbulence - collaboration with NATO (completed 1970). | | |
| | 99. | Flight loads on pipeline survey and agricultural aircraft (completed 1970). | | |
| | 100. | Assessment of prototype V-G-H recorder (completed 1970). | | |
| | 101. | Stress analysis studies of multi-cell caissons, DPW (completed 1972). | | |
| | 102. | Fatigue certification of Trident aircraft - consultation - DITC (completed 1972). | | |
| | 103. | In collaboration with DND, MOT and NATO - compilation of turbulence data (completed 1972). | | |
| | 104. | Computer controlled simulation of operational dynamic loads for aircraft fatigue tests (completed 1972). | | |

| List of Projects, Activity II-1 (continued | | 1968 | 1975 |
|---|---|---|---|
| NAE 105. | Coaxial cable investigations, MOT (completed 1973). | | |
| 106. | V-G-H recorder data analysis for DND (completed 1974). | | |
| 107. | Forces in ship mooring structures - DPW (completed 1974). | | |
| 108. | Operational load monitoring of aircraft structures (completed 1974). | | |
| 109. | Study of fluidic amplifiers. | x | |
| 110. | Research on airspeed sensing - pitot-static tubes. | x | |
| 111. | Development of low-velocity anemometer. | x | |
| 112. | Theory of axisymmetric hypersonic intakes. | x | |
| 113. | Aerodynamics of "externally blown flap" for high lift of STOL aircraft (completed 1971). | | |
| 114. | Dispersal of exhaust gases from a twin-hulled vessel (completed 1972). | | |
| 115. | Bridge deck studies - Arvid, Grand and Associates (completed 1973). | | |
| 116. | DDH 280 funnels - DND (completed 1974). | | |
| 117. | Snow plow visibility - water tunnel studies, Ontario, MOTC. | | x |
| 118. | Externally-blown jet flap studies (completed 1974). | | |
| 119. | Snow deflector characteristics for hot box detectors, CN. | | |
| 120. | Determination of bow shock wave in axisymmetric transonic flow. | | x |
| 121. | Determination of vertical acceleration derivatives at transonic and supersonic speeds. | | x |
| 122. | Wind tunnel studies on a "ground effect" aerofoil. | | x |

| List of Projects, Activity II-1 (continued) | | 1968 | 1975 |
|---|---|---|---|
| NAE 123. | Non-linear spatial wave development in an axisymmetrical turbulent jet. | | x |
| 124. | Influence of body flexibility on stability of sounding rockets. | x | |
| 125. | Wind tunnel wall effects on V/STOL models | x | |
| 126. | V/STOL aircraft propeller-wing interactions. | x | |
| 127. | Study of fluidic amplifiers and sensors. | x | x |
| 128. | Aerodynamic stability of bridges (Northumberland Strait Crossing) (completed 1969). | | |
| 129. | Assessment of radiation hazards of supersonic transport (completed 1969). | | |
| 130. | Flutter investigation Lockheed L1011 (completed 1969). | | |
| 131. | Transonic flow characteristics for Lockheed aircraft (completed 1969). | | |
| 132. | DeHavilland fan-jet simulation studies (completed 1970). | | |
| 133. | Annular jet thrust augmentor (completed 1970). | | |
| 134. | Momentum theory of unyawed propellers (completed 1970). | | |
| 135. | Wind induced opening of railway car loading doors (completed 1970). | | |
| 136. | Aerodynamic characteristics of tilt wing V/STOL system (completed 1970). | | |
| 137. | Analysis of configuration for minimum energy requirements in slow flight (completed 1970). | | |
| 138. | Twin hull sounding vessel - DSS (completed 1971). | | |
| 139. | Tunnel tests Ski-doo TNT 1973, Bombardier Ltd. (completed 1971). | | |
| 140. | Harmonic oscillations of a thick wedge in hypersonic flow (completed 1971). | | |

| List of Projects, Activity II-1 (continued) | | | 1968 | 1975 |
|---|---|---|---|---|
| NAE | 141. | Dynamic stability of straight and delta wing space shuttle about separation at M = 1.80 (completed 1971). | | |
| | 142. | Transonic aerofoil development (completed 1971). | | |
| PHY | 143. | Optical aspects of airport control tower cab design. | | x |
| II-2 | | Energy | | |
| DBR | 1. | Solar heating of buildings. | | x |
| | 2. | Use of insulation in buildings. | | x |
| | 3. | Ventilation and air quality. | | x |
| | 4. | Lighting. | | x |
| | 5. | Energy conservation demonstrations. | | x |
| CHE | 6. | Magnetic, electrical, thermal properties of metals and alloys. | x | x |
| | 7. | Photochemical isotope enrichment by laser radiation (PIE Project). | x | |
| | 8. | Mass spectrometry. | x | |
| | 9. | Chemistry of atmospheric pollution. | x | x |
| | 10. | Radiation damage in solids. | x | |
| | 11. | Catalytic processes in hydrocarbon chemistry. | | x |
| | 12. | Oxidation of liquid petroleum compounds. | x | x |
| | 13. | Mass spectrometry. | x | |
| DEE | 14. | Studies of radio interference from DC corona. | x | x |
| | 15. | Corona loss measurements. | x | x |
| | 16. | Dielectric breakdown. | x | x |
| | 17. | Evaluation of conductor configuration. | x | x |

| | List of Projects, Activity II-2 (continued) | 1968 | 1975 |
|---|---|---|---|
| DEE | 18. Study of safe clearance under HVDC lines. | x | |
| DME | 19. Hydrogen as a fuel for mobile vehicles. | | x |
| | 20. Low temperature flow properties of diesel and heating fuels (completed 1974). | | |
| | 21. Hydrogen storage as metal hydrides. | | x |
| | 22. Feasibility of methane/carbon dioxide as tractor fuel. | | x |
| | 23. Stability of compressed fuel gas mixtures. | | x |
| NAE | 24. Finite element vibration analysis of multiconductor electrical transmission lines (completed 1973). | | |
| | 25. Vibrations and stability of electrical power transmission lines. | | x |
| | 26. Power transmission twin-bundle sub-conductor oscillations (completed 1970). | | |
| | 27. STOL and VTOL research with helicopter airborne simulator (completed 1971). | | |
| | 28. Wind induced oscillation of bundled power conductors (completed 1973). | | |
| | 29. Aerodynamics of bundled conductors - Hydro Quebec (completed 1971). | | |
| | 30. Dynamics of three-conductor models - Aluminum Company of Canada (completed 1971). | | |
| | 31. Aerodynamic studies of Model 4-propeller tilt wing transport (completed 1971). | | |
| | 32. Galloping power transmission lines (completed 1972). | | |
| | 33. Aluminum Company of Canada, wind turbulence effects on "Bundle Conductor Transmission Line Span" (completed 1974). | | |
| | 34. Vertical axis wind turbine development. | | x |

| | | List of Projects, Activity II-2 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| PHY | 35. | The scattering of light by a plasma to obtain detailed information on the energy distribution and the cooperative motions of the charged particles. | x | |
| | 36. | The above technique (35) is now being applied to laser produced plasmas. | | x |
| | 37. | The construction of a high intensity short pulse laser (pulses with a duration of less than $10^{-10}$ sec). | x | |
| | 38 | Intense light pulses generated by a laser can cause sparks in gases. The nature of these sparks is being investigated by a number of methods. | x | x |
| | 39. | Large aperture atmospheric pressure UV preionized $CO_2$ lasers have been developed and a laser system capable of generating nanosecond pulses at energies of ~ 100J will be used for the production of plasmas from a variety of plane and spherical targets. | | x |
| | 40. | UV-preionized $CO_2$ lasers capable of operating at gas pressures up to 15 atmospheres have been developed. Operation at such pressures has permitted the construction of a continuously tunable $CO_2$ laser and the generation of ultra-short pulses ($<10^{-10}$ secs) of infra-red radiation. | | x |
| | 41. | The application of the optical Kerr effect to ultra-high speed photography has yielded exposure times of a few picoseconds and has also permitted the development of a new technique for spectroscopic measurements on a picosecond time scale. A novel mode-locking technique based on the optical Kerr effect is also under investigation. | | x |
| | 42. | Diagnostic techniques for use with $CO_2$ laser radiation (~10μm wavelength) are being developed. One approach is to shift the radiation frequency by means of a nonlinear upconversion process and this technique has permitted the detection of pulses shorter than $10^{-10}$ seconds. Image recording systems employing special heat-sensitive films or pyro-electric vidicons are also under investigation. | | x |

| List of Projects, Activity II-2 (continued) | | 1968 | 1975 |
|---|---|---|---|
| PHY | 43. A number of diagnostic techniques are being used to investigate the interaction of high power $CO_2$ laser radiation with plasmas. These include time-resolved measurements of backscattered laser radiation at power densities $>10^{13}W/cm^2$, sub-nanosecond laser interferometry for the measurement of electron densities exceeding $10^{19}cm^{-3}$ and the use of a novel magnetic probe to record the megagauss magnetic fields associated with such plasmas. | | x |
| | 44. An electron-optical streak camera with a temporal resolution of ~5 psecs has been developed, and used for the investigation of mode-locked Nd: glass laser pulses. Improvements to the original streak camera are being incorporated and work is in progress to extend the range of such devices to the soft X-ray region. | | x |
| | 45. Special techniques for the control and synchronization of nanosecond $CO_2$ laser pulses are being developed. These include active mode-locking by means of high frequency modulators, injection mode-locking and high-speed switching by means of optically induced carriers in semiconductors. A fast plasma switch to protect large $CO_2$ oscillator/amplifier systems from back reflected radiation has been developed. | | x |
| | 46. A basic MHD computer code to study the interaction of intense $CO_2$ laser pulses with solid targets is undergoing continuing development. Particular emphasis is being placed on modelling thermally generated magnetic fields, and preliminary results indicate that such fields can play a dominant role in the dynamics of $CO_2$ laser-blowoff plasmas. | | x |
| | 47. Basic theoretical work related to laser-plasma interactions is being carried out and the rate of energy transfer between waves in a weakly turbulent magnetized plasma has been analyzed and compared with the rate of absorption of wave energy. | | x |
| II-3 | Food | | |
| ARL | 1. Systematics and ecology of marine algae. | x | x |
| | 2. Growth of phytoplankton organisms in pure culture. | x | x |

| | | List of Projects, Activity II-3 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| ARL | 3. | Biochemistry and physiology of marine algae. | x | x |
| | 4. | Chemistry of the constituents of marine algae. | | x |
| | 5. | Genetics of marine algae. | | x |
| | 6. | Cultivation of seaweeds. | x | x |
| | 7. | Production of toxic substances by fungi isolated from Nova Scotia pastures and effect on ruminants. (Cooperative research project with Agriculture Canada). | x | x |
| | 8. | Taxonomy and chemistry of lichens and the biosynthesis of lichen substances. | x | x |
| | 9. | Separation and chemical characterization of toxins produced by fungi. (In cooperation with CNRS, France). | | x |
| | 10. | Effects of processing procedures and storage conditions on the contamination by micro-organisms of | | |
| | | (a) poultry | x | |
| | | (b) beef. | x | x |
| | 11. | Effects of pre- and post-slaughter treatment on beef quality. | x | x |
| | 12. | Storage of vegetables at high humidity. | x | x |
| | 13. | Anaerobic methanogenic fermentation. | | x |
| | 14. | Storage of fresh and frozen beef in relation to centralized prepackaging. | | x |
| | 15. | Biochemistry and physiology of plant cells grown in submerged culture: | | |
| | | (a) secondary metabolites, | | x |
| | | (b) plant cell and tissue culture collection. | | x |
| CHE | 16. | Microbiological deterioration. | x | x |
| | 17. | Deterioration of fats and oils. | x | |
| NAE | 18. | Utilization of aircraft in agriculture and forestry. | x | x |

| | List of Projects, Activity II-3 (continued) | 1968 | 1975 |
|---|---|---|---|
| NAE | 19. Hail suppression experiments, Alberta Research Council. | x | x |
| | 20. Aerial spray systems (completed 1972). | | |
| PRL | 21. Obligate parasitism in microorganisms. | x | |
| | 22. Effects of rapeseed oil in diets of chickens and turkeys. | x | |
| | 23. Effect of composition of dietary oils on the depot fats of mice, rats, and chickens. | x | |
| | 24. Biosynthesis of fatty acids in flax and sunflower seed. | x | |
| | 25. Plant ribosomal proteins. | x | |
| | 26. Biosynthesis of thioglucosides. | x | |
| | 27. Composition of fats. | x | |
| | 28. Determination of thioglucosides in rapeseed and rapeseed meals. | x | |
| | 29. Symbiotic nitrogen fixation of legumes and microorganisms. | x | x |
| | 30. Analytical methods for lipids. | x | x |
| | 31. Chemical reactions of lipids. | x | x |
| | 32. Composition of oil and waxes from wheat leaf and stem. | x | x |
| | 33. Biosynthesis of plant proteins. | x | x |
| | 34. Structure of plant proteins. | x | x |
| | 35. Growth and maintenance of plant cell cultures. | x | x |
| | 36. Metabolism of plant growth regulators. | x | x |
| | 37. Continuous culturing of plant cells. | x | x |
| | 38. Biosynthesis of RNA in plant cells. | x | x |
| | 39. Synthesis and chemistry of oilseed proteins. | x | x |

| | | List of Projects, Activity II-3 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| PRL | 40. | Composition of plant leaf waxes. | x | x |
| | 41. | Nitrogen fixation: | | |
| | | (a) Control of nitrogenase activity. | x | x |
| | | (b) Plant microbe symbiosis. | | x |
| | | (c) Rhizobium strains. | | x |
| | | (d) Genetic analysis of symbiotic nitrogen fixation. | | x |
| | | (e) In vitro transfer of genetic information. | | x |
| | | (f) Legume carbon metabolism. | | x |
| | 42. | Plant cell culture: | | |
| | | (a) Differentiation and asexual regeneration of plants. | x | x |
| | | (b) Nutrition and culture. | x | x |
| | | (c) Genetics. | | x |
| | | (d) Protoplasts. | | x |
| | | (e) Isoenzymes. | | x |
| II-4 | | Building and Construction | | |
| DBR | 1. | Effect of weather factors (wetting and sunlight) on cracking and peeling of house paints. | x | |
| | 2. | Study of basic mechanical properties and gas and vapour permeability of clear coatings. | x | |
| | 3. | Evaluation of field performance of paints on steel substrates at eight corrosion sites across Canada. | x | |
| | 4. | Evaluation of field performance of different plastics at four sites in Canada. | x | |
| | 5. | Measurement of rate and extent of joint movement in buildings to which sealants are subjected. | x | |
| | 6. | Effect of temperature and weathering on the mechanical and adhesive properties of a number of types of sealants. | x | |
| | 7. | Dimensional changes to cement paste resulting from wetting and drying. | x | |

| | | List of Projects, Activity II-4 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| DBR | 8. | Physical, mechanical and mineralogical changes in hydrated cement resulting from organic chemical admixtures. | x | |
| | 9. | Effects of freezing on durability and stability of hydrated cement and other porous materials. | x | |
| | 10. | Destructive reaction of some dolomitic limestone aggregate with alkali in concrete. | x | |
| | 11. | Measurement of atmospheric corrosion of various architectural metals at eight sites across Canada. | x | |
| | 12. | The wetting and freezing of masonry walls, effect of orientation and resulting lack of durability. | x | |
| | 13. | Deterioration of concrete in the Maritimes associated with certain aggregates. | x | |
| | 14. | Deterioration of concrete on the Prairies resulting from high sulphate content in soils. | x | |
| | 15. | Instability of brick masonry due to certain combinations of different bricks and mortars. | x | |
| | 16. | Basic engineering properties of concrete. | x | x |
| | 17. | Properties and performance of joint materials. | x | x |
| | 18. | Performance of concrete as revealed by its micro-structure. | x | x |
| | 19. | Performance of foamed plastic insulation. | x | x |
| | 20. | Performance of clear and pigmented coatings. | | x |
| | 21. | Durability to frost action in concrete and other porous materials. | | x |
| | 22. | Processes of degradation of organic building materials. | | x |
| | 23. | Performance of concretes as related to the chemical processes in cements. | | x |

| | List of Projects, Activity II-4 (continued) | 1968 | 1975 |
|---|---|---|---|
| DBR | 24. Performance of structural masonry. | | x |
| | 25. Repair of building materials. | | x |
| | 26. Performance of Canadian aggregate. | | x |
| | 27. Performance of concrete in the presence of aggressive solutions. | | x |
| | 28. Weathering factors and accelerated test methods for assessing durability of organic building materials. | | x |
| | 29. Properties and performance of bituminous roofing systems. | | x |
| | 30. The performance and maintenance of materials in buildings and structures. | | x |
| | 31. Air and rain leakage through windows and curtain wall joints. | x | |
| | 32. Weather data for air-conditioning design. | x | |
| | 33. Heat transfer between engineering structures and the ground. | x | |
| | 34. Computer methods for calculating heating and cooling requirements. | x | |
| | 35. Water vapour permeability of materials. | x | |
| | 36. Heat flow in moist materials. | x | |
| | 37. Condensation on surfaces of double windows. | x | |
| | 38. Hygrothermal properties of materials. | x | x |
| | 39. Hermetically sealed double glazing. | x | x |
| | 40. Thermal performance of walls and windows. | x | x |
| | 41. Air movement in buildings. | x | x |
| | 42. Plumbing studies. | | x |
| | 43. Air conditioning systems. | | x |
| | 44. Insulated underground piping. | | x |

| | List of Projects, Activity II-4 (continued) | 1968 | 1975 |
|---|---|---|---|
| DBR | 45. Factors affecting breakage of window glass. | x | |
| | 46. Precast concrete studies. | x | |
| | 47. Strength of wood frame houses. | x | |
| | 48. Strain gauges in concrete. | x | |
| | 49. Snow engineering. | x | |
| | 50. Meteorology. | x | |
| | 51. Study of swelling and shrinking clays and their effect on shallow foundations. | x | |
| | 52. Engineering properties of peat and its field behaviour. | x | |
| | 53. Thermal insulation of roads with foamed plastic. | x | |
| | 54. Deformation and stresses in soils. | x | x |
| | 55. Soil strength and rapid failures. | x | x |
| | 56. Deep foundations and excavations. | x | x |
| | 57. Regional studies. | x | x |
| | 58. Frost action in soils. | x | x |
| | 59. Ice engineering. | x | x |
| | 60. Deformation and strength of frozen and thawing soils. | | x |
| | 61. Ground thermal regine. | | x |
| | 62. Frost heave forces on foundations - Thompson, Manitoba. | | x |
| | 63. Tunnelling and underground construction. | | x |
| | 64. Model studies of the behaviour of foundations in frozen ground. | | x |
| | 65. Rheology and strength of saline ice. | | x |
| | 66. MacKenzie Highway embankment study. | | x |

| | List of Projects, Activity II-4 (continued) | 1968 | 1975 |
|---|---|---|---|
| DBR | 67. Development of sound insulation criteria. | x | |
| | 68. Reverberation rooms and sound absorption measurements. | x | |
| | 69. Computer simulation of buildings and their seismic response. | x | |
| | 70. Calculation and measurement of building vibration modes. | x | |
| | 71. Sound insulation - field tests and surveys. | x | |
| | 72. Building and ground vibrations produced by blasting and by construction equipment. | x | |
| | 73. Theoretical and experimental studies of sound transmission through walls. | x | |
| | 74. Environmental vibrations in laboratories. | x | |
| | 75. Development of impact test for floors. | x | x |
| | 76. Acoustical test methods (sound transmission, sound absorption, sound power). | x | x |
| | 77. Development of noise criteria. | | x |
| | 78. Insulation of buildings from external noise. | | x |
| | 79. Determination of dynamic response characteristics of structures. | | x |
| | 80. Measurement of sound power of noise sources. | | x |
| | 81. Outdoor noise propagation. | | x |
| | 82. Propagation of dynamic disturbances in soils. | | x |
| | 83. Study and promotion of good practices in winter building. | x | |
| | 84. Investigation of roofing failures and promotion of improved practices. | x | |
| | 85. Investigation of wall and window failures and the development and promotion of improved design details. | x | |

| | List of Projects, Activity II-4 (continued) | 1968 | 1975 |
|---|---|---|---|
| DBR | 86. Survey of the maintenance records of public housing in Ontario. | x | |
| | 87. Assessment of slab-on-ground foundation design and construction methods. | x | |
| | 88. Observations of NHBA experimental houses. | x | |
| | 89. Condensation in house roofs in Inuvik. | x | |
| | 90. Methods of evaluation of structural adhesives for enclosure panels. | x | |
| | 91. Cost study of house painting. | x | |
| | 92. Water pick-up of house footing drain tile (jointly with OWRC). | x | |
| | 93. System building in Europe. | x | |
| | 94. Documentation of building details. | | x |
| | 95. Construction accuracy. | | x |
| | 96. Building maintenance. | | x |
| | 97. Metric conversion and modular coordination. | | x |
| | 98. Masonry staining and cleaning and use of protective coatings. | x | |
| | 99. Comparison of local outdoor curing and laboratory curing of cement-lime mortars. | x | |
| | 100. Materials and services performance. | x | x |
| | 101. Masonry studies. | x | x |
| | 102. Performance of building materials and components in prairie weather conditions. | x | |
| | 103. Mechanical equipment for humidification, ventilation and heating of buildings. | x | |
| | 104. Moisture measurement. | x | x |
| | 105. Sorption and transmission of moisture in some building materials. | x | x |

| List of Projects, Activity II-4 (continued) | | | 1968 | 1975 |
|---|---|---|---|---|
| DBR | 106. | Roofing studies. | x | x |
| | 107. | Shallow foundations on active subsoils. | x | x |
| | 108. | Concrete in soils of high sulphate content. | x | x |
| | 109. | Compression characteristics of glacial deposits in Western Canada. | | x |
| | 110. | Thermal and moisture aspects of building environments. | x | x |
| NAE | 111. | Aerodynamic stability of bridges. | x | |
| | 112. | Wind characteristics in Locna Lake Valley, B.C. | x | |
| | 113. | CGE models of heavy-water plant towers (completed 1969). | | |
| | 114. | Aerodynamics of bridge components - Dominion Bridge Company (completed 1971). | | |
| | 115. | Aerodynamics of nuclear power plant towers (completed 1971). | | |
| | 116. | Aerodynamics of bridge components - Spear, Northrup Assoc. (completed 1972). | | |
| | 117. | Aerodynamics evaluations of building projects - Vancouver Square Holdings (completed 1972). | | |
| | 118. | Aerodynamics studies of 250 ft. multi-flue chimney, Francis Hankin Co. (completed 1972). | | |
| | 119. | Water tunnel investigations of snow shed for switch installations, Iron Ore Co. (completed 1972). | | |
| | 120. | St. Scholastique Airport Control tower model, CAIM (completed 1972). | | |
| | 121. | Aerodynamic effects on Place Desjardins complex (completed 1972). | | |
| | 122. | Measurement of wakes downwind from arrays of tall buildings (completed 1972). | | |
| | 123. | Wellington Street Site Development, NCC, (completed 1973). | | |

| List of Projects, Activity II-4 (continued) | | | 1968 | 1975 |
|---|---|---|---|---|
| NAE | 124. | Wind tunnel study, Canadian Government Building No. 3, DPW (completed 1973). | | |
| | 125. | Project West - wind tunnel investigation Concordia Estates (completed 1973). | | |
| | 126. | Studies of snow accumulation on hangar roof - Ernest A. Dahl Associated (completed 1973). | | |
| | 127. | Studies of blow-off resistance of stone on IRMA roof, Dow Chemical Co. (completed 1974). | | |
| | 128. | Wind environment studies, Teron Construction Company (completed 1973). | | |
| | 129. | Canatom Monmax - aerodynamics of elevator tower model. | | x |
| | 130. | Fatigue of structural grade steel bolts. | x | |
| | 131. | Fatigue of high strength steel butt-welded plates (completed 1969). | | |

## III RESEARCH IN DIRECT SUPPORT OF INDUSTRIAL INNOVATION AND DEVELOPMENT

### III-2 NRCL Contract Research

| | | | | |
|---|---|---|---|---|
| NAE | 1. | Certification procedures, Saunders Aircraft Corp., ST-27 aircraft (completed 1969). | | |
| | 2. | Flight simulation projects - Vereinigte Flugtech. Werke (completed 1970). | | |
| | 3. | Take-off and landing performance, Saunders ST-27 aircraft (completed 1970). | | |
| | 4. | Handling quality problems on VAK 191B aircraft, VFW Fokker (completed 1971). | | |
| | 5. | High altitude turbulence measurements- Nat. Severe Storm Lab (completed 1971). | | |
| | 6. | Stability and calibration of trailing bomb system, DND (completed 1971). | | |
| | 7. | Static thrust evaluations for CF-5D aircraft - Computing Devices of Canada (completed 1972). | | |

| | List of Projects, Activity III-2 (continued) | 1968 | 1975 |
|---|---|---|---|
| NAE | 8. Take-off and landing performance of Saunders ST-27 aircraft (completed 1972). | | |
| | 9. Spray droplet analyses, Min. des Terres et Forets, P.Q. | | x |
| | 10. Airborne gravimetric measurements, EMR. | | x |
| | 11. Chemical Control Research Institute - aircraft monitoring and analysis. | | x |
| | 12. Assessment of the Canadian Aerodyne Project. | | x |
| | 13. Aerodynamics study of DeHavilland augmentor wing. | x | |
| | 14. Canadair CL-41G-5 aircraft stores jettisoning. | x | |
| | 15. Canadair CL-215 study of water release. | x | |
| | 16. DeHavilland ducted fan. | x | |
| | 17. DRB CARDE Jezex configurations. | x | |
| | 18. Aerodynamics of Bristol Aerospace tactical met. rocket. | x | |
| | 19. High Reynolds Number Boeing 2-D high lift wing. | x | |
| | 20. DeHavilland models WTA, WTBC, WTBA and WTZ. | x | |
| | 21. Aerodynamics of DRB "Moby" model. | x | |
| | 22. Transonic flow characteristics for Lockheed Aircraft. | x | |
| | 23. Aerodynamic instability studies of Wullenweber High Band Antennae (completed 1969). | | |
| | 24. Aerodynamic wing balance for DRB "Moby" model (completed 1969). | | |
| | 25. Flexible body stability studies of Bristol Aerospace RDT & E rocket (completed 1969). | | |
| | 26. DeHavilland models WTS, WTA4, WTZ IV, WTZ V (completed 1969). | | |

List of Projects, Activity III-2 (continued) 1968 1975

NAE 27. Aerodynamic assessment of SHARC fin, Leigh Instruments (completed 1969).

28. Rb05 missile firing from SAAB aircraft (completed 1969)

29. Studies of airframe elasticity effects on SAAB aircraft (completed 1969).

30. Aerodynamic studies of Canadair model CL-215 (completed 1969).

31. Studies of Canadair CL-228-1A11 high lift system (completed 1969).

32. Boeing Company Model TR1145-M-1, aerodynamic investigations (completed 1969).

33. High speed aerodynamic studies, Boeing Co. Model TR1116-M-1 (completed 1969).

34. Aerodynamic characteristics Space Research Institute Rocket Augmented Vehicle (completed 1969).

35. SAAB two dimensional airfoils - aerodynamic studies (completed 1969).

36. Nacelle drag model studies, United Aircraft Company (completed 1969).

37. Airframe elasticity effects - SAAB aircraft 37 (completed 1970).

38. DeHavilland WTAW, WTA, WTBE models (completed 1970).

39. Aerodynamics of NACA 65-213 airfoil - Canadian Commercial Corp (completed 1970).

40. Stability characteristics of spinning model with wrap around fin stabilizers - DRB (completed 1970).

41. Douglas Aircraft - aerodynamics investigations (completed 1970).

42. Convair two-dimensional transonic studies (completed 1970).

List of Projects, Activity III-2 (continued) 1968 1975

NAE 43. Canadair Limited - high lift program (completed 1970).

44. High Reynolds Number Investigations - SAAB airfoil sections (completed 1970).

45. Static stability studies during missile launching - Space Research Corp. (completed 1970).

46. Rigid model investigation, with external stores, SAAB aircraft 37 (completed 1970).

47. Aerodynamics of Douglas Aircraft Model LB-305B (completed 1970).

48. Flow visualization bubble generator - Sage Action Inc. (completed 1970).

49. Aerodynamic overturning of prefabricated homes in transit, Alcan (completed 1970).

50. Douglas Aircraft - aerodynamics of 10" chord model (completed 1971).

51. Douglas Aircraft - aerodynamics of model LB-305E (completed 1971).

52. Rocket studies - DREV (completed 1971).

53. Stability and control investigation - SAAB aircraft 37 (completed 1971).

54. Investigation and handling qualities of VAK 191B aircraft, VFW-Fokker (completed 1971).

55. McDonnell Aircraft - two-dimensional transonic airfoil studies (completed 1971).

56. Stability and calibration of AETE trailing bomb system, DND (completed 1971).

57. Air-intake study at high subsonic speed, SAAB, (completed 1971).

58. AS-5034/SRL antenna studies - Canadian Westinghouse Company (completed 1971).

59. Aerodynamics of structural members - Barber Machinery Co. (completed 1971).

| List of Projects, Activity III-2 (continued) | 1968 | 1975 |
|---|---|---|

NAE 60. DeHavilland - lateral/directional control characteristics of STOL aircraft (completed 1971).

61. DeHavilland Aircraft Model WTBJ, WTA, WTBP, WTBN (completed 1972).

62. Douglas Aircraft - 2D tests on airfoil models (completed 1972).

63. Stability and drag characteristics of Canadair CL-289 drone (completed 1972).

64. Spinning tubular projectile, DREV (completed 1972).

65. FFA Aerodynamic Research Institute, Sweden - effect of Reynolds Number on swept-wing body configuration at transonic speeds (completed 1972).

66. Canadair CL-215 aerodynamic evaluations (completed 1972).

67. Dynamic cross-derivatives on aircraft-like vehicles - NASA Ames Research Lab. (completed 1972).

68. Dynamic characteristics of bridge components - Dominion Bridge Co. (completed 1972).

69. Convair (General Dynamics) - jet flap evaluations (completed 1972).

70. Canadair Limited - CL-84 AEW model (completed 1973).

71. Schematic models of swept wing aircraft - SAAB (completed 1973).

72. Wiper blades, Tridon Ltd. (completed 1973).

73. DeHavilland - models WTBJ, WTY III, WTBK, WTBP, WTBE (completed 1973).

74. Aerodynamic studies of SAAB aircraft 37, rigid model, SAAB, Scania (completed 1973).

75. DeHavilland - 2-D investigation of augmentor wing (completed 1973).

76. DeHavilland - wind tunnel model components (completed 1973).

List of Projects, Activity III-2 (continued) 1968 1975

NAE 77. PT6-Exhaust stub studies - United Aircraft of Canada Ltd. (completed 1973).

78. Transonic investigation of three ONERA models, Champlain Power Products (completed 1973).

79. SAAB - swept wing model with leading and trailing edge manoeuvring flaps (completed 1973).

80. Aerodynamic investigation of VTOL transport Aircraft,

81. Deep diving tender model studies, DND (completed 1973).

82. Motorcycle water tunnel tests, CAN-AM Bombardier Ltd. (completed 1973).

83. Aerodynamic investigations model LB368A, Douglas Aircraft Co. (completed 1973).

84. Wind deflectors on bauxite ship - Aluminum Co. of Canada (completed 1973).

85. Wind tunnel studies Port aux Basques/North Sydney Ferry, German and Milne Co. (completed 1973).

86. Canadair Ltd. - CL 253 contra-rotating rotor investigation (completed 1973).

87. High Reynolds number investigation of two dimensional airfoils, SAAB-Scania (completed 1973).

88. Canadair Ltd. - CL 289 Reconnaissance Drone. (completed 1973).

89. SAAB-Scania, Stability and control studies RB72-12 (completed 1974).

90. Wind characteristics, LaPrade Heavy Water Plant, Dominion Bridge Co. Ltd. (completed 1974).

91. DeHavilland models WTBJ, WTY, WTBK (completed 1974).

92. Wind tunnel studies of motorcycles, Can. Am. Bombardier Ltd. (completed 1974).

| | | List of Projects, Activity III-2 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| NAE | 93. | Wind characteristics of Holiday Inn model, Sankey Arcop. (completed 1974). | | |
| | 94. | ERSB 155 mm. spinning projectile, Space Research Corp. (completed 1974). | | |
| | 95. | Ship unloader model studies, Aluminum Co. of Canada Ltd. (completed 1974). | | |
| | 96. | Force measurements, Lions' Gate Bridge model, Buckland and Taylor Ltd. (completed 1974). | | |
| | 97. | Supercritical LC100D airfoil aerodynamics, ONERA (completed 1974). | | |
| | 98. | 2-D investigation of augmentor wing, DeHavilland Aircraft (completed 1974). | | |
| | 99. | Determination of dynamic cross derivatives on aircraft-like vehicles, NASA (completed 1974). | | |
| | 100. | McDonnell Douglas Aircraft, advanced transonic airfoil studies (completed 1974). | | |
| | 101. | Calford Project, wind characteristics, Calford Prop. Ltd. (completed 1974). | | |
| | 102. | Wind blast effects on strain recorders, Leigh Instruments Ltd. (completed 1974). | | |
| | 103. | SAAB-Scania, peaky airfoil section aerodynamics (completed 1974). | | |
| | 104. | Wind climate studies on Oxford Square Project, Calgary (completed 1974). | | |
| | 105. | SAAB-Scania, stability and control of RB72-12. | | x |
| | 106. | DeHavilland - WTBP, WTBK, WTY, WTBV. | | x |
| | 107. | "R" class icebreaker model studies, Burrard Drydock Co. | | x |
| | 108. | Wind blow-off studies, Dow Chemical Co. | | x |
| | 109. | Ducted fan characteristics, DeHavilland of Canada Ltd. | | x |
| | 110. | ILS localizer antenna studies, Philips Electronics. | | x |
| | 111. | Tractor-trailer air drag characteristics, CP Transport. | | x |

| List of Projects, Activity III-2 (continued) | | 1968 | 1975 |
|---|---|---|---|
| NAE 112. | Aerodynamic investigations of aircraft 37 rigid model, SAAB-Scania. | | x |
| 113. | DeHavilland ejectro thrust calibration. | | x |
| 114. | Study of dynamic cross-derivatives, NASA. | | x |
| 115. | Aerodynamic characteristics of I-Beam Hangars, Howard, Needles, Gammen & Bergendorf. | | x |
| 116. | DeHavilland Aircraft - 2-D investigation of augmentor wing at high subsonic speed. | | x |
| 117. | Hudson Bay "electromagnetic bird," Hudson Bay Exploration and Development Co. | | x |
| 118. | Wind characteristics "Oxford Square Project," Oxford Development Group. | | x |
| 119. | Aeroelastic model studies of Lions' Gate Bridge, Buckland and Taylor. | | x |
| 120. | Canadair Ltd., CL-289 booster balance and sting. | | x |
| 121. | Douglas Aircraft, model LB-368C | | x |
| 122. | Aerodynamic studies of Crash Position Indicator, Leigh Instruments Ltd. | | x |
| 123. | Fatigue investigation on the Canadair CL-41 aircraft (completed 1969). | | |
| 124. | Bird impact studies on TUTOR aircraft windscreen DND (completed 1969). | | |
| 125. | Flight impact simulator, DeHavilland, PPG Industries Inc., (completed 1970). | | |
| 126. | Full scale fatigue test of CL-41 tutor aircraft DND (completed 1970). | | |
| 127. | Powder-metallurgy of nickel-based superalloys United Aircraft of Canada Ltd. (completed 1970). | | |
| 128. | Northern Electric Co., fatigue of satellite components (completed 1970). | | |
| 129. | Bird impact studies on aircraft structures, North American Rockwell Corp. (completed 1971). | | |

| List of Projects, Activity III-2 (continued) | | | 1968 | 1975 |
|---|---|---|---|---|
| NAE | 130. | DeHavilland - Bird impact studies on aircraft windscreens (completed 1971). | | |
| | 131. | Full-scale fatigue test of CL-41 Tutor aircraft, DND (completed 1971). | | |
| | 132. | Acoustic noise effects on foamed and composite plastics, Leigh Instruments (completed 1972). | | |
| | 133. | DeHavilland DHC-7 canopy, bird impact studies (completed 1974). | | |
| | 134. | Bird impact studies on panels, PPG Industries Ltd. (completed 1974). | | |
| | 135. | Investigation of submarine cable-splicing techniques, MOT (completed 1974). | | |
| | 136. | Coin-press load studies, Royal Canadian Mint (completed 1974). | | |
| | 137. | Bird impact studies on windscreens, Federal Express Ltd. (completed 1974). | | |
| | 138. | Target deployment, observer response data system, Foundation of Canada Engineering Corp. (completed 1974). | | |
| | 139. | Experimental stress analysis of dockboards, Magline of Canada Ltd. (completed 1974). | | |
| | 140. | Acoustical noise studies on strain recorders, Leigh Instruments Ltd. (completed 1974). | | |
| | 141. | Bird Impact Studies, PPG Industries Ltd. | | x |
| | 142. | Acoustic research, R.A. Ramsay Co. | | x |
| | 143. | Elevated temperature fatigue studies of coated A286 alloy, DND. | | x |
| | 144. | Ballistic tests of "Belly Band" joint designs, Pratt and Whitney Aircraft Ltd. | | x |
| | 145. | Retaining ring tests, Boeing of Canada Ltd. | | x |
| PRL | 146. | Processing of Nigerian grains. | | x |

| III-3 | NRCL Non-Contract Research | 1968 | 1975 |
|---|---|---|---|
| ARL | 1. Reactions of liquid silicates at high temperatures. | x | x |
| | 2. Reactions of gases with liquid metals and decarbonization of liquid iron-carbon alloys. | x | x |
| | 3. Constitution and thermodynamic properties of silicate melts and glasses. | x | x |
| | 4. Viscosity of metallurgical slags, with emphasis on the refining of lead and steel. (In cooperation with Brunswick Mining and Smelting Corp. and Sydney Steel Corporation). | | x |
| | 5. Removal of sulfur from coal, coke and steel during processing. (In cooperation with scientists at the Nova Scotia Technical College, Dalhousie University, Nova Scotia Research Foundation Corporation, Energy, Mines and Resources, Sydney Steel Corporation). | | x |
| CHE | 6. Upgrading of impure water by reverse osmosis. | x | x |
| | 7. Separation of suspended solids in liquids by inclined settling and spherical agglomeration. | x | x |
| | 8. Separation of solids in packed fluidized beds. | x | x |
| | 9. Enlargement of particle size. | | x |
| | 10. Stability characteristics of suspensions. | x | x |
| | 11. Small particle technology. | x | x |
| | 12. Novel rapid printing methods. | x | x |
| | 13. Extension of steam tables. | x | x |
| | 14. P.V.T. properties of vapors and liquids. | | x |
| | 15. Accurate measurement of high pressures. | x | x |
| | 16. Lignin reinforcement of rubbers. | x | |
| | 17. Molding and testing of rubber products. | x | |
| | 18. Catalytic processes in hydrocarbon and petroleum chemistry. | x | x |

| | List of Projects, Activity III-3 (continued) | 1968 | 1975 |
|---|---|---|---|
| CHE | 19. Combustion properties | | x |
| | 20. X-ray crystallography. | x | x |
| DEE | 21. Precision current comparator and potentiometer. | x | x |
| | 22. Technique for calibrating voltage. | x | x |
| | 23. Provision of routine calibration services to industry. | x | x |
| | 24. High voltage testing of transmission hardware for industry. | x | x |
| | 25. Computer-controlled display development. | x | x |
| | 26. Audio disc and changer (CPDL arranging for licensed production). | | x |
| | 27. Line-concentrator development. | | x |
| | 28. Ultrasonic touch-sensitive overlay (being produced under license by Instronics Ltd., Stittsville, Ont.). | x | |
| | 29. Ground terminal equipment for reception of weather satellite signals (basis for commercial equipment now used by DOT) | x | |
| | 30. Passport card automation. | | x |
| | 31. Computer controlled display techniques. | x | x |
| | 32. Digital data systems. | x | |
| | 33. Computer interfaces. | x | |
| | 34. Development of radar altimeter for forest inventory studies. | x | x |
| | 35. Development and testing of antennas for government and industry. | x | x |
| | 36. Industrial application of microwave energy. | x | x |
| | 37. Microwave acoustics research. | | x |
| | 38. Optical processing studies. | | x |

| | List of Projects, Activity III-3 (continued) | 1968 | 1975 |
|---|---|---|---|
| DEE | 39. Development of ultrahigh vacuum transfer device for samples. | | x |
| | 40. Echoencephalography. | x | x |
| | 41. Communication aids for the handicapped. | | x |
| DME | 42. Gas turbine engine icing tests. | x | |
| | 43. Centrifugal compressor and fan aerodynamics. | x | |
| | 44. Development of lightweight foamed-clay building materials using spent sulphite liquor from paper mills (completed 1972). | | |
| | 45. Fundamental studies of friction, lubrication and wear (completed 1974). | | |
| | 46. Wear and damage of shotgun barrels (completed 1974). | | |
| | 47. Barrier coatings for ball bearings (completed 1974). | | |
| | 48. Analytical techniques for exhaust gas analysis. | | x |
| | 49. Reduction of oxides of nitrogen. | | x |
| | 50. Theoretical and experimental studies of novel bearings. | | x |
| | 51. Practical studies in tribology. | | x |
| | 52. Waste oil collection, recovery and re-use. | | x |
| | 53. Static electricity generation in distillate fuels. | | x |
| | 54. Acoustic seeding in combustion processes. | | x |
| | 55. Boiling point distribution by gas chromatograph. | | x |
| | 56. Design and development of a non-contacting system for the measurement of the variation in small distances, i.e. of the order of 0.0001 inch, in operating machinery (completed 1969). | | |

| List of Projects, Activity III-3 (continued) | | | 1968 | 1975 |
|---|---|---|---|---|
| DME | 57. | Development of a force-balance type transducer suitable for both airborne and ground use and manufacture of a prototype punched paper recorder for use with this transducer as a self-contained statistical data gathering system (completed 1970). | | |
| | 58. | Laboratory tests of experimental sensing devices for the continuous measurement of thickness of boards during log sawing. | x | |
| | 59. | Measurements of the vibration characteristics of a range of chain saws of a particular make, for study of the operator acceptability of these designs (completed 1969). | | |
| | 60. | Investigation of problems reported by pulp and paper industry, in regard to mill operation of a new commercial form of consistency meter (completed 1971). | | |
| | 61. | Discussions with the pulp and paper industry as to the applicability of existing mini computer hardware to their instrumentation and control problems (completed 1972). | | |
| | 62. | Assistance to a Canadian firm in the development of instrumentation required to monitor papermaking machine dynamics. | | x |
| | 63. | Improvement to the sensitivity of a corrosion detection device to be used in pipelines on site for a Canadian industry (completed 1974). | | |
| | 64. | Assistance to a government forest products laboratory in improving their temperature control of a wood chip silo used in reducing chip deterioration (completed 1973). | | |
| | 65. | Investigation of industrial systems applications of fluidic circuits. | x | x |
| | 66. | In collaboration with the Dept. of Energy, Mines and Resources, an investigation of the process dynamics and control characteristics of an electric arc furnace for processing iron ore. | x | x |
| | 67. | Dynamic modelling of electric arc and oxygen steel-making processes. | x | x |

| | List of Projects, Activity III-3 (continued) | 1968 | 1975 |
|---|---|---|---|
| DME | 68. Investigation of the process dynamics and control characteristics of a copper converter. | x | x |
| | 69. Simulation models applied to industrial operations. | | x |
| NAE | 70. Aerodynamics of Laval University ellipsoid. | x | |
| | 71. Modular intake studies with McGill University. | x | |
| | 72. Research on shockless high-lift transonic aerofoils with Convair and NY University (completed 1970). | | |
| | 73. High Reynolds number pipe flow, with Laval University (completed 1974). | | |
| PHY | 74. Accurate, semi-automatic measurement of high resistance values. | | x |
| | 75. Development of an instrument for measuring salinity, temperature and depth in ocean water. | x | |
| | 76. Design of instruments for electrical and oceanographic studies. | | x |
| | 77. Development of a laser type range finder. | x | |
| | 78. Development of a $CO_2$ laser suitable for length measurements. | x | x |
| | 79. Optical thin films. | | x |
| | 80. Design of an artificial daylight source. | x | |
| | 81. A study of the reflectivity of surfaces at various angles. | x | |
| | 82. Colour grading maple syrup. | x | |
| | 83. Development of test procedures for air survey cameras. | | x |
| | 84. Development and maintenance of the Sudbury test area. | x | x |
| | 85. Development of analytical methods of correcting air survey photographs for mapping. | x | x |

| List of Projects, Activity III-3 (continued) | | 1968 | 1975 |
|---|---|---|---|
| PHY | 86. Design and construction of a new type stereo orthophoto mapper. | x | |
| | 87. Development of an electrical method of measuring lengths and angles. | x | |
| | 88. Analytical photogrammetry: computer programs. | | x |
| | 89. Analytical on-line photogrammetry. | | x |
| | 90. Non-cartographic photogrammetry. | | x |
| | 91. Geodetic problems related to photogrammetry. | | x |
| | 92. Orthophoto and stereo-orthophoto techniques. | | x |
| | 93. Construction of a new model of the analytical plotter for map making. | x | |
| | 94. Electronic control systems for photogrammetry; automation. | | x |
| PRL | 95. Polysaccharides from yeasts. | x | |
| | 96. Biosynthesis of hydroxy acids by yeasts. | x | |
| | 97. Utilization of jack pine as a pulp source. | x | |
| | 98. Solvent pulping of native woods and straw. | x | |
| | 99. Fractionation of plant proteins to provide protein concentrate. | x | x |
| | 100. Carbohydrates in legume seeds and cereals. | | x |
| | 101. Production and utilization of legume seeds; flour, protein, starch. | | x |

IV RESEARCH TO PROVIDE TECHNOLOGICAL SUPPORT OF SOCIAL OBJECTIVES

IV-1 Public Safety

| | | 1968 | 1975 |
|---|---|---|---|
| BIO | 1. Improvement of security measures and the detection of contraband at Canadian airports. | | x |
| | (A collaborative project by the Division of Biological Sciences, the NAE, the RCMP, Revenue Canada, and other authorities.) | | |

| | | List of Projects, Activity IV-1 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| CHE | 2. | Serviceability of textiles. | x | x |
| DBR | 3. | Fire behaviour in high buildings and its implications for design. | x | |
| | 4. | Statistical analysis of deaths due to fire in Ontario. | x | |
| | 5. | Effect of lining materials on the spread of fire in corridors. | x | |
| | 6. | Properties of building materials from the viewpoint of their behaviour in fire. | x | |
| | 7. | Extinguishment of building fires by inert gas and high expansion foams. | x | |
| | 8. | International Cooperative Research Project: The development of fire in an enclosure. | x | |
| | 9. | Thermal decomposition of polymers. | | x |
| | 10. | Behaviour of building components in fire. | | x |
| | 11. | Evaluation of fire behaviour of plastic components. | | x |
| | 12. | Ignitability and flame spread studies. | | x |
| | 13. | Production and movement of smoke in fire. | | x |
| | 14. | Fire protection features of buildings. | | x |
| | 15. | Development of fire. | | x |
| | 16. | Combustion of organic materials. | | x |
| | 17. | Toxicity of combustion products. | | x |
| | 18. | Timber beams and columns. | | x |
| | 19. | Fire resistance safety factors. | | x |
| | 20. | Restraint and fire severity. | | x |
| | 21. | Ignitability of furnishing materials | | x |
| | 22. | Deformation and failure of fresh water ice. | x | x |
| | 23. | Avalanche engineering. | x | x |

| | List of Projects, Activity IV-1 (continued) | 1968 | 1975 |
|---|---|---|---|
| DBR | 24. Avalanche hazard evaluation. | | x |
| | 25. Movement of people in buildings. | x | x |
| DEE | 26. Police science studies. | | x |
| | 27. Pattern recognition and image processing. | | x |
| | 28. Shipboard antenna development. | x | x |
| | 29. Antenna development for CHSS-2 helicopter | x | |
| NAE | 30. Helicopter crash position indicator. | x | x |
| | 31. Evaluation of infra-red spectrometer as a clear air turbulence detector. | x | |
| | 32. Forest fire control by aerial methods. | x | |
| | 33. Range trials of C5A radio beacon airfoil. | x | |
| | 34. Investigation of CF-TJM aircraft crash at Ottawa. | x | |
| | 35. Eddy current re-compensation of Argus aircraft (completed 1969). | | |
| | 36. Flight data recorder readout facilities. | | x |
| | 37. Triggering of automotive safety devices for occupant protection (completed 1972). | | |
| | 38. Flight recorder data analysis facility, MOT, DND (completed 1973). | | |
| | 39. Investigation of CF-PWZ aircraft accident at Edmonton (completed 1973). | | |
| | 40. Investigation of CF-EPL aircraft incident, Churchill Falls, Nfld. (completed 1973). | | |
| | 41 Sensing device for activation of passenger restraint systems in automobiles (completed 1973). | | |
| | 42. Automobile crash-detector sensing device. | | x |
| | 43. DeHavilland DHC-5 Buffalo Aircraft - bird impact studies (completed 1971). | | |

| | List of Projects, Activity IV-1 (continued) | 1968 | 1975 |
|---|---|---|---|
| NAE | 44. Aviation Security Program - Transport Canada. | | x |
| | 45. Explosion containment studies (completed 1974). | | |
| | 46. Explosion vapour detection studies. | | x |
| | 47. Fracture analysis by electron microscopy. | x | x |
| | 48. Automobile de-icing and demisting. | x | |
| | 49. Automobile cable-barrier impact dynamics. | x | x |
| | 50. Technical advice to Courts by automobile safety group (completed 1969). | | |
| | 51. Instrumentation for sensing and recording automobile and driver parameters (completed 1971). | | |
| | 52. Disabling of fleeing vehicles - RCMP (completed 1972). | | |
| | 53. Aerodynamic noise generation and radiation in supersonic jets (completed 1972). | | |
| | 54. Collaboration with American Society for Metals in preparation of Metals Handbook, Vol. 9, "Fractography and Atlas of Fractographs" (completed 1973). | | |
| | 55. Investigation of fire destruction, Air Canada DC-8 CF-TIJ at Malton, MOT (completed 1973). | | |
| | 56. Automobile driver response analysis (completed 1973). | | |
| | 57. Automobile rear-window defogging evaluations, MOT (completed 1972). | | |
| | 58. Automobile headlight evaluation, Motor Vehicle Traffic Safety Office, MOT. | | x |
| | 59. Collaboration with American Society for Metals, Metals Handbook, Vol. 10 on "Failure Analysis" (completed 1974). | | |
| | 60. Passenger Processing Booth, MOT (completed 1974). | | |

| | | List of Projects, Activity IV-1 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| NAE | 61. | Research on the re-direction of vehicles by cable barriers. | | x |
| | 62. | System for research studies of driver control movements. | | x |
| IV-2 | | Environment | | |
| BIO | 1. | Bioaccumulation and toxicity of chlorinated hydrocarbons. | x | x |
| | 2. | Bioaccumulation and toxicity of compounds of mercury. | | x |
| | 3. | Biology and physiology of freshwater vascular plants. | | x |
| | 4. | Determination of transport, distribution, and biological impact of trace elements and organic pollutants in rivers. | | x |
| | 5. | Formulation and validation of mathematical models of pollutant movement in aquatic ecosystems. | | x |
| | 6. | Partition and movement of mercury between sediment, water, and suspended material in aquatic ecosystems. | | x |
| | 7. | Modelling of the dispersion of radionuclides in air. | | x |
| | 8. | Development and compilation of scientific criteria for environmental quality. | | x |
| CHE | 9. | Spark source mass spectrometry. | x | x |
| | 10. | Gas chromatography. | x | x |
| | 11. | Flameless atomic absorption spectroscopy | | x |
| | 12. | X-ray fluorescence spectroscopy. | x | x |
| | 13. | Atomic absorption spectroscopy. | x | x |
| | 14. | Infrared spectroscopy. | x | x |
| DBR | 15. | Permafrost distribution. | x | x |

| List of Projects, Activity IV-2 (continued) | | | 1968 | 1975 |
|---|---|---|---|---|
| DBR | 16. | Permafrost environmental studies. | x | x |
| DEE | 17. | Engineering services for Alberta Hail Research Project. | x | |
| NAE | 18. | Forest fire control by aerial methods (completed 1972). | | |
| | 19. | Analysis of severe turbulence leading to pilot disorientation (completed 1969). | | |
| | 20. | Flight data recorder analysis (completed 1969). | | |
| | 21. | CPI soft landing systems (completed 1969). | | |
| | 22. | Low level turbulence studies, NATO, AGARD (completed 1970). | | |
| | 23. | Airborne acquisition of atmospheric data over Great Lakes, DOE (completed 1972). | | |
| | 24. | Flight studies of INCO Sudbury plume, Environment Canada. | | x |
| | 25. | Summer cumulus cloud project, Environment Canada. | | x |
| | 26. | Spray card analysis, Environment Canada (completed 1974). | | |
| | 27. | Dispersion of airborne pollutant studies (completed 1974). | | |
| | 28. | Cloud physics studies, Environment Canada. | | x |
| | 29. | Studies of mechanism and alleviation of jet noise. | | x |
| | 30. | Study of physico-chemical processes in upper atmosphere (completed 1971). | | |
| | 31. | Simulation of natural wind characteristics over cities (completed 1972). | | |
| | 32. | Water tunnel simulation facilities (completed 1972). | | |

| | List of Projects, Activity IV-2 (continued) | 1968 | 1975 |
|---|---|---|---|
| NAE | 33. Air pollution problems associated with pesticides and agricultural spraying (completed 1972). | | |
| | 34. Wind tunnel research of aerial spraying of insecticides. | | x |
| | 35. Atmospheric distribution of gaseous and aerosol pollutants. | | x |
| | 36. Gas phase reaction kinetics with reference to upper atmosphere composition. | | x |
| | 37. Maintenance of standards, and calibration of instruments. | x | x |
| | 38. Study of jet noise suppression (completed 1969). | | |
| | 39. Aerodynamic noise generation and radiation in supersonic jets (completed 1972). | | |
| | 40. Production and alleviation of aerodynamic noise (completed 1972). | | |
| PHY | 41. Reduction of noise in axial blowers. | x | |
| | 42. Statistical studies of traffic noise. | x | |
| | 43. Effect of noise on sleeping persons. | | x |
| | 44. Wave acoustics of the human external ear in relation to hearing measurement, hearing conservation and earphone design. | | x |
| | 45. Outdoor sound propagation with particular reference to aircraft and motor vehicle noise. | | x |
| | 46. Measurements and abatement of community noise levels. | | x |
| | 47. Reduction of noise from small internal combustion engines. | | x |
| | 48. Research and feasibility studies on acoustical instruments and devices. | | x |
| | 49. Measurements of the effects of temperature, salinity, and pressure on the electrical conductivity of sea water. | | x |

| | | List of Projects, Activity IV-2 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| PHY | 50. | Radiation shielding; personnel protection. | | x |
| PRL | 51. | Microbial degradation of aromatic, alicyclic, and halogenated compounds related to pesticides. | x | x |
| | 52. | Waste products in spent bleach from pulp mill. | x | |
| IV-3 | | Health | | |
| BIO | 1. | Antigenic glycopeptides from dermatophytes. | x | |
| | 2. | Cell-wall polysaccharides from Penicilliae. | x | |
| | 3. | Mannans from pathogenic yeasts. | x | |
| | 4. | Polysaccharides from dermatophytes. | x | |
| | 5. | Structure of antigenic lipopolysaccharides. | x | x |
| | 6. | Synthetic antigens from carbohydrates. | x | x |
| | 7. | Measurement of the metabolism of inorganic radiochemicals in laboratory animals. | x | x |
| | 8. | Microdistribution of plutonium in bone. | | x |
| | 9. | Antigens from Neisseria Gonorrhoeae. | | x |
| | 10. | Antigens from Neisseria Meningitidis. | | x |
| | 11. | Antigens from Neisseria Pneumococcus. | | x |
| | 12. | Synthesis of a biologically-active gene. | | x |
| | 13. | Synthetic approaches to penicillins. | | x |
| | 14. | Interactions between nucleic acids and proteins. | | x |
| | 15. | Development of a general in vitro test for carcinogenesis. | | x |
| | 16. | Genetic control of cytoplasmic inheritance. | | x |
| | 17. | Induction of mutations by environmental mutagens. | | x |
| | 18. | Action of carcinogens and drugs on membrane structure. | | x |
| | 19. | Relationships between hormone structure and activity. | | x |

| | List of Projects, Activity IV-3 (continued) | 1968 | 1975 |
|---|---|---|---|
| BIO | 20. Structure of antigenic polysaccharides. | | x |
| DEE | 21. Cardiac arrhythmia analysis. | x | |
| | 22. Biological energy sources. | x | |
| | 23. Cardiac pacemaker studies. | x | x |
| | 24. Cardiac diagnostic instruments. | x | |
| | 25. Eye biometrics research. | | x |
| | 26. Transport incubator. | | x |
| | 27. Computer cardiac analysis. | | x |
| | 28. Electromagnetic radiation of biological specimens. | | x |
| DME | 29. Construction for clinical use of two similar devices for the intradermal injection of pigment. | x | x |
| | 30. Continued assistance in the use of vascular suturing instruments in clinical transplant surgery at local hospitals. Design, construction, and development of a semi-automatic staple loader for the commercial form of the NRC-Vogelfanger Vascular Suturing Instrument. | x | x |
| | 31. Development of a prosthetic venous valve modelled on the clinical valve. Preparation of experimental cannula systems for evaluation in experimental surgery of a modified anti-thrombogenic treatment. | | x |
| | 32. Evaluation of changes to Harrington equipment for treatment of scoliosis. Construction of two experimental tools to facilitate the Harrington procedure for spinal surgery. | x | |
| | 33. Design and manufacturing of hydraulic pump for use as power unit for mechanically driven lower limb orthesis. | x | |
| | 34. Development of an implantable moulded vessel for the Physiology Section, Animal Research Institute, Dept. of Agriculture (completed 1970). | | |

| List of Projects, Activity IV-3 (continued) | | 1968 | 1975 |
|---|---|---|---|
| DME | 35. In collaboration with the Vancouver General Hospital, a modified form of external tension-relieving "splint" for counteraction of eviscerating forces and preventing of dehiscence of incisions closed with very low tensile strength suture material (completed 1971). | | |
| | 36. Consideration of a new form of artificial knuckle joint (completed 1971). | | |
| | 37. Preliminary design consideration of (i) instrument for end-to-side suturing of blood vessels, (ii) and aid in plastic surgery to facilitate the suturing on surgical incisions (1971 and 1974). | | |
| | 38. Design, construction, and testing of an unpowered, manually controlled, hydraulic device for a lower limb prosthesis. The hydraulic unit provides control of knee bending action, unimpeded straightening and automatic locking of the knee. | | x |
| | 39. Development, construction, and evaluation of a device for the measurement of foot angle about the patient's leg axis (to obtain the degree of "club foot" condition). | | x |
| | 40. Design of an artificial finger joint prosthesis moulded in high density polyethylene. | | x |
| | 41. Improvement of aids for handicapped readers. A page turner has been developed. | | x |
| | 42. Collaboration with UBC and Vancouver General Hospital authorities in design and manufacture of a convertible bed/chair arrangement for the easier handling and better comfort of extremely disabled persons. | | x |
| | 43. Development of a moving base simulator for human operator studies (completed 1969). | | |

| List of Projects, Activity IV-3 (continued) | 1968 | 1975 |
|---|---|---|
| DME 44. A general program of research and development in the human factors engineering field that includes the following: | | |
| (a) Investigation of the control characteristics of the human operator and the basic phenomena underlying tracking performance. | x | x |
| (b) Investigation of the nature of sensory interaction in human perceptual-motor performance. | x | x |
| (c) Investigation of the factors involved in the presentation and processing of information, particularly in relation to simulator design. | x | x |
| 45. Development of an analog correlator for processing EEG signals. | x | |
| 46. Investigation of neuromuscular control system - Part I - inhibition of nerve conduction. | x | |
| 47. A general program of research and development in the biological engineering field that includes the following: | | |
| (a) Investigation of the implementation of feedback control in living organisms. | x | x |
| (b) Investigation of data transmission processes, with particular reference to nerve conduction characteristics. | x | x |
| (c) Investigation of auditory methods of monitoring electro-physiological signals in general and the electroencephalograph in particular (completed 1970). | | |
| (d) Development of depth probes for the study of electrical activity in the deep structures of the human brain (completed 1969). | | |
| (e) Development of stereo-taxic and other apparatus for neurosurgical procedures. | x | x |

| | | List of Projects, Activity IV-3 (continued) | 1968 | 1975 |
|---|---|---|---|---|
| DME | 47. | Continued | | |
| | | (f) Development of a phase memory filter for electro-encephalograph studies (completed 1969). | | |
| | | (g) Investigation of muscle control by electro-stimulation (completed 1973). | | |
| | | (h) Development of heat-exchanger and instrumentation for reducing and controlling the temperature of the spinal cord at a site of injury. | | x |
| | | (i) Accelerated wound healing by EM field and chemical treatment. | | x |
| | 48. | Investigation of the fundamentals of pattern recognition. | x | x |
| | 49. | Development of techniques for the identification of biological cell populations, fingerprints, etc. | x | x |
| | 50. | Methods by which ultrasonics may be used to break up large number of medical pills prior to content analysis (completed 1971). | | |
| | 51. | Techniques developed for the successful moulding of high density polyethylene (RCH1000) for use in bio-engineering applications (completed 1974). | | |
| PHY | 52. | Vibration of chain saws in relation to circulatory disorders of the hands. | | x |
| IV-4 | | Education and Training | | |
| DBR | 1. | Structures in permafrost. | x | x |
| | 2. | Earthquake engineering. | x | |
| DEE | 3. | Multi-computer network development and operation for CAL research. | | x |
| | 4. | National course authorizing language. | | x |
| | 5. | Speech synthesis. | | x |
| | 6. | Hybrid and time-shared analog-computer systems. | x | x |

| | List of Projects, Activity IV-4 (continued) | 1968 | 1975 |
|---|---|---|---|
| DEE | 7. Computer analysis of sound. | x | |
| | 8. Software for computer aids to the handicapped | | x |
| | 9. Specialized CAL operating system for CAN-6 language | | x |
| | 10. Aids for the blind. | x | x |
| | 11. Mobility aids and biofeedback. | | x |
| V | NATIONAL FACILITIES | | |
| V-1 | Scientific Research Facilities | | |
| NAE | 1. Construction of 30-ft. wind tunnel. | x | |
| | 2. Completion and calibration of 30-ft. V/STOL wind tunnel (1969). | | |
| | 3. Development of Flow-Visualization Water Tunnel (1970). | | |
| | 4. Enhancement and calibration of transonic performance of high speed wind tunnel (1970). | | |
| | 5. Flight impact simulator, PPG industries (completed 1973). | | |
| PHY | 6. Installation and testing of the linear electron accelerator and the positive ion accelerator. | x | |
| | 7. Operation of 35 MeV linear electron accelerator for projects listed above and for nuclear physics research in cooperation with members of universities. | | x |
| | 8. Operation of 4 MeV positive ion accelerator for projects listed above and for nuclear physics research in cooperation with member of universities. | | x |

| List of Projects, Activity V-2 | | 1968 | 1975 |
|---|---|---|---|
| V-2 | Engineering Test Facilities | | |
| NAE | 1. Fatigue life monitoring of Canadian Armed Forces Aircraft - DND. | | x |
| V-3 | Observational Facilities | | |
| DEE | 1. Non-scanning R.F. spectrometer for Radio Astronomy. | | x |
| | 2. 22 GHz radiometer | | x |
| | 3. 3.2 GHz radiometer. | | x |
| | 4. Special instrumentation for long base line interferometry. | | x |
| | 5. Digital frequency expander. | | x |
| HIA | 6. Operation and maintenance of the Algonquin Radio Observatory. | x | x |
| | 7. Development of new radiometers for the Algonquin Radio Observatory. | | x |
| | 8. Operation and maintenance of the Dominion Astrophysical Observatory. | x | x |
| | 9. Operation and maintenance of the Dominion Radio Astrophysical Observatory. | x | x |
| VI | RESEARCH AND SERVICES RELATED TO STANDARDS | | |
| VI-1 | Primary | | |
| PHY | 1. Calibration of instruments. | x | x |
| | 2. Measurement of the variation in resistance of standard resistors which are dissipating power. | x | |
| | 3. Calibration of reference standards and measuring instruments for outside laboratories. | x | x |
| | 4. Measurement of alternating voltage ratios at low frequencies. | | x |
| | 5. Automatic intercomparison of standard cells. | | x |
| | 6. Semi-automatic calorimeter for measurement of microwave power. | | x |

| List of Projects, Activity VI-1 (continued) | | 1968 | 1975 |
|---|---|---|---|
| PHY | 7. Semi-automatic swept-frequency measurement of coaxial impedance. | | x |
| | 8. Accurate measurement of alternating voltage, current and power at 60 Hz. | | x |
| | 9. Design of high temperature furnaces and a study of the melting point of antimony. | x | |
| | 10. Participation in an international test of thermocouple wire at high temperature. | x | |
| | 11. Determination of the reliability of high temperature measurements with an optical pyrometer. | x | |
| | 12. Maintenance of, and research towards, continuing improvement in Canadian temperature standards and the International Practical Temperature Scale. | | x |
| | 13. Studies of the properties and performance of platinum metal thermocouples for precision thermometry. | | x |
| | 14. Development of precision platinum resistance thermometers for high temperatures and study of their applicability to the International Practical Temperature Scale. | | x |
| | 15. Development and implementation of a time-shared direct-digital-control computer system. | | x |
| | 16. Calibration of the reference standards of length, mass, force and pressure for the Department of Consumer and Corporate Affairs in accordance with the Act respecting Weights and Measures (1971). | x | x |
| | 17. Calibration of reference standards of length, diameter, angle, geometrical form, surface configuration, mass, force, torque, pressure, density and specific gravity for Canadian industry, government and university. | x | x |
| | 18. International comparison of hardness measurements. | x | x |

| List of Projects, Activity VI-1 (continued) | | | 1968 | 1975 |
|---|---|---|---|---|
| PHY | 19. | Precision instrument design in the fields mentioned in 17. | | x |
| | 20. | Primary length standard interferometry. | | x |
| | 21. | A study of the relative spectral sensitivity of photodiodes. | x | |
| | 22. | Design, production and use of electrically calibrated absolute radiometers to establish radio-metric and photometric scales. | | x |
| | 23. | Improvement of the cesium clock and an international comparison of time standards. | x | x |
| | 24. | Development of the hydrogen maser frequency standards. | x | x |
| | 25. | Development of a calorimetric method of measuring absorbed dose of radiation. | x | x |
| | 26. | X-, $\gamma$-ray, electron and neutron dosimetry for medical use, industry and research. | | x |
| | 27. | Development of primary measurements of radio-activities for use in nuclear physics and radiation therapy. | | x |
| | 28. | Studies of electron capture, positron and electron emission probabilities in nuclear decay. | | x |
| | 29. | Neutron flux determination and neutron spectroscopy for radiation protection and research. | | x |
| VI-2 | Engineering | | | |
| DEE | 1. | Refinements in HV impulse measurements (cooperative work through International Electrotechnical Commission). | x | x |
| DME | 2. | Standards for petroleum products. | | x |
| NAE | 3. | Maintenance of standards and calibration of instruments. | x | x |

| | List of Projects, Activity VI-2 (continued) | 1968 | 1975 |
|---|---|---|---|
| PHY | 4. The dissemination of specialized technical information pertinent to those areas of VI-1 mentioned in 17, 18 and 19. Also in the areas of fundamental units and engineering standardization. | | x |
| | 5. Test of the resolution of films in air survey cameras. | x | |
| | 6. Sensitometric properties of photographic color films for aerial photography under normal and adverse conditions. | | x |
| | 7. Secondary frequency standards and time scales and related calibration facilities. | | x |
| | 8. Time dissemination by CHU shortwave station. | | x |
| VI-3 | Industrial Standards and Codes | | |
| CHE | 1. Evaluation of textile properties and development of test methods. | x | x |
| DBR | 2. Assistance to NBC, CSA, ACI and CIB Committees in preparation of codes and standards. | x | |
| | 3. Structural safety. | x | x |
| | 4. Snow loads on roofs. | x | x |
| | 5. Wind effects on buildings and structures. | x | x |
| | 6. Stability of structures and progressive collapse. | | x |
| | 7. Masonry research. | | x |
| | 8. Fire performance information. | | x |
| | 9. Studies relating to earthquake load provisions of the 1975 National Building Code. | | x |
| | 10. Occupancy standards developed from experience. | | x |
| | 11. Study of occupancy classification. | | x |
| DEE | 12. Electrical Standards in Health Care. | x | x |
| PHY | 13. Improvement of measurements of absolute reflectance of matte and glossy materials. | | x |

| SCIENTIFIC AND TECHNICAL INFORMATION PROGRAM | 1968 | 1975 |
|---|---|---|
| This program was initiated as a separate entity within NRC in 1973 and was funded by separate parliamentary vote in fiscal year 1975/76. Projects of component units prior to 1973 are included. | | |
| 1. Canadian Selective Dissemination of Information (CAN/SDI): a computer-based alerting service. | x | |
| 2. Development of MEDLARS Service for the retrieval of medical references (completed 1969). | | |
| 3. Development of Canadian Subject Retrieval Program (CAN/SRP) for industrial access to the Technical Information Service's "Tech Briefs" files (completed 1969). | | |
| 4. Development of the Pollution Information Program (PIP): pollution data base and on-line retrieval service developed as an interim measure until international data bases became available (completed 1974). | | |
| 5. Development of a National Scientific and Technical Information System. | | x |
| 6. Development of an Information Exchange Centre for Federally-Supported University Research (completed 1971). | | |
| 7. Development of a Canadian On-line Enquiry System (CAN/OLE): an interactive, computer-based retrieval system for bibliographic references. | | x |
| 8. Development of Canadian Audio Cassette Tapes (CAN/ACT) Service: technology transfer by audio media (completed 1972). | | |
| 9. Cooperative Industrial Student Project: students hired by small and medium industries who are supervised by Technical Information Service officers (completed 1972). | | |

| List of Projects (continued) | 1968 | 1975 |
|---|---|---|
| 10. The Vibank Project (Professor Slingerland, Laval University): experimental data bank service in mechanical vibrations (completed 1974). | | |
| 11. Data Compression Project (Professor Heaps, Concordia University): practical techniques for improving computer storage on magnetic media (completed 1974). | | |
| 12. Development of Canadian Industrial Reference Guides (CAN/IRG): lists of reference material in 305 application areas (completed 1973). | | |
| 13. Development of Canadian Government Information Sources of Interest to Industry (CAN/GIS): lists of sources of technical information in federal service (completed 1974). | | |
| 14. The Application of Welding Technology to Agricultural Implements (Saskatchewan Research Council). | | x |
| 15. Development of a Knowledge Source Index: a method of accessing the personal expertise of Canada's "resident experts" in science and technology. | | x |

In addition to the above projects, the following research journals were developed during the period 1968 to 1975:

- Canadian Geotechnical Journal (1969)
- Canadian Journal of Forest Research (1972)
- Canadian Journal of Civil Engineering (1974)

2.9 2. Case Histories — Page

Basic Research



Applied Research

SYNTHESIS OF THE LACTOSE-OPERATOR GENE OF E. COLI

The history of this project goes back some 10 years and is based upon a decision that one of the major future directions of organic chemistry would be towards its applications in biology and biochemistry. Accordingly, two young scientists were engaged, one with interests in peptide synthesis (polymers of amino acids), the other interested in synthesis of nucleic acids (polymers of nucleotides). The latter, Dr. S.A. Narang, had been a research associate with Dr. H.G. Khorana and had contributed substantially to the work for which the Nobel Prize was awarded.

Dr. Narang set out to develop practical methods for the synthesis of nucleic acids with the eventual aim of synthesizing a gene. Basically, this involves the condensation of four different nucleotides (phosphorylated ribosyl bases) in known sequences that duplicated the sequence in a natural gene. The initial stage was to find improved methods for condensing two nucleotides and then extension of those methods to the condensation of larger blocks. Results of this phase of the research yielded new condensing reagents and new phosphorylating reagents. The next phase of the work was to devise better methods for separating condensation products from unreacted starting material. The magnitude of this problem is best illustrated by an example. Suppose that an 8-membered polynucleotide is to be condensed with

a trinucleotide to give an 11-membered nucleotide. Even if the condensation is 90% effective (a high yield for an organic reaction) there will be 10% of unreacted starting compounds along with the desired product. The mixture then contains polynucleotides with degrees of polymerization of 3, 8, and 11. The trinucleotide is sufficiently smaller to be separated from the other two but there is little chemical or physical difference between the 8- and 11-membered products. The problem becomes even greater as the nucleotide chain gets longer as required for gene synthesis. To solve this problem Dr. Narang devised ways to insert a specific chemical grouping into the desired product and also developed an affinity chromatography procedure for isolation of compounds with that grouping. Another major step in the project was the discovery that nucleotides beyond a certain degree of polymerization could be condensed by an enzyme, "ligase".

With the development of efficient condensation methods (both chemical and enzymic) and separation techniques the work turned to the practical synthesis of a gene. The one chosen was the "lac-operon" of E. coli because it was relatively short as genes go (21 nucleotides), the specific sequence of nucleotides in the gene had been established, and its biological activity could be assayed through specific binding by its repressor protein that was also available. This synthesis was completely successful and represents the first synthesis of a gene with full biological activity.

The series of papers that have reported this work have been accepted by the most prestigious scientific journals in the world and have attracted wide attention in the scientific community. Dr. Narang has received an award from the Indian Chemical Society of which several previous winners are now Nobel Laureates, he has received numerous requests to lecture on his work and has been invited as a feature speaker at the next congress of the Organic Chemistry Division of the International Union of Pure and Applied Chemistry. There is little doubt that the procedures developed here are generally accepted throughout the scientific community as the best and most practical approach to gene synthesis. The impact of this work is likely to be even greater as progress is made in recombinant DNA experiments, the so-called genetic engineering. Again, an example will help to explain. It is theoretically possible to extract, from a pancreas, genetic material that contains the gene that codes for insulin. This genetic material could then be introduced into the common bacterium _E. coli_, by recombinant DNA techniques, and there would be a reasonable possibility that the _E. coli_ would then produce insulin as a metabolic product. One could then produce insulin in whatever quantities desired by a simple fermentation procedure independent on any animal source. The problem arises in that the genetic material from a pancreas contains many other genes, in addition to the insulin gene, whose

activities are unknown and unpredictable under recombinant conditions. That is the reason why animal-bacteria recombinant DNA experiments have been banned by mutual agreement within the scientific community. However, the objections would be greatly reduced if the genetic material introduced in the recombinant DNA was totally synthetic, chemically and biologically defined, and free of any extraneous or "hidden" genes. The advances made here in the synthesis of polynucleotides represent at least a first step towards that goal.

It is interesting to note that this project provides demonstration (in addition to the one on pathogenic bacteria) of the difficulty of distinguishing between "basic" and "applied" research in biological science. Although this project has been categorized as "basic", it has yielded <u>four</u> patents. One of these has already been licenced and the product is being marketed. Other companies are actively negotiating for licences of the other three patents. Thus, the so-called "basic" research has yielded four new products that the chemical industry considers worthwhile.

## STUDIES OF MUONIC ATOMS AND QUANTUM ELECTRODYNAMICS

Evolution of scientific knowledge comes, in large part, from a continuing interaction between experimental observations and theoretical models. The latter try to synthesize and simplify the former; the former challenges and tests the predictions of the latter. Better measurements usually lead to better theories and so advance our understanding of nature.

The interrelated phenomena of electricity and magnetism are extremely well understood. The theory that describes electromagnetic interactions at very small distances is called quantum electrodynamics (QED) and is by far the most successful of the modern "basic" theories, incorporating both quantum mechanics and special relativity.

The very success of QED is a special challenge to experimental physicists. Here theory is "ahead of" the experiments! There are a number of different precise measurements which critically test QED and one of the most critical of these is the determination of the values of certain transition energies in muonic atoms. A muonic atom consists of an atomic nucleus (any nucleus from hydrogen to uranium and beyond) to which is bound one negatively-charged muon, a heavy electron-like particle. Muons can be produced by particle accelerators with energies over a few hundred million electron volts and are spontaneously

radioactive with a lifetime of two millionths of a second. In two millionths of a second it is possible, however, to bring the artificially-created muon to a chosen target, to slow it down so that it can be captured by a nucleus in the target so forming a muonic atom, and to study the properties of that atom. The muonic atom has many of the features of the ordinary hydrogen atom, one of the best understood of all the fundamental physical systems; at the same time it has special properties, due to the large mass of the muon, which makes it more sensitive to some effects than is the ordinary atom.

In the early 1960's the NRC High Energy Physics group was involved in experiments with muonic atoms in collaboration with physicists at the University of Chicago, using muons produced by the University of Chicago cyclotron. (There were no accelerators in Canada of sufficiently high energy to produce muons.) They used the then currently standard sodium iodide crystal spectrometer to measure the energies of muonic atom "x-rays". (It should be noted that while ordinary atomic x-rays have energies in the thousands of electron volts region, muonic atom x-rays may run into millions of electron volts, an energy region usually associated with nuclear gamma rays.)

In 1964 came a break-through in technique. Scientists at the Chalk River Nuclear Laboratories of AECL developed the germanium crystal gamma ray spectrometer and applied it

successfully to nuclear gamma ray measurements. The early germanium spectrometer had about ten times better energy resolution than the old sodium iodide spectrometer, and so permitted energy measurements to correspondingly higher accuracy. The NRC group borrowed one of the first germanium spectrometers from Chalk River and took it to Chicago to make the first muonic x-ray measurements with the new device. A series of experiments at Chicago followed (with Carleton University joining the collaboration) which led to a number of new interesting results. Among the results of the NRC-Carleton-Chicago collaboration were the first observation of well-resolved fine structures splitting due to the spin of the muon, the first observation of resolved hyperfine splitting due to static and dynamic interactions with nuclei via their electron quadrupole moments, precise measurements of isotope shifts, polarization of heavy nuclei by the muon and radiationless transitions in the atom accompanied sometimes by nuclear neutron emission. By 1970 it was realized that improvements in germanium crystal resolution together with new electronic circuit measuring techniques developed at NRC and Carleton could be applied to make a critical test of the QED theory.

The results of the first experiment designed for this purpose, published in 1971, were, to everyone's surprise, in serious disagreement with the predictions of QED. Shortly

after, an independent measurement made in Europe was published and confirmed the discrepancy.

During the next four years a large number of theoretical papers appeared. Some corrected errors in earlier work, some refined the calculations, and others proposed novel explanations for the discrepancy. As a result the gap between theory and experiment was narrowed, but not completely closed, and so new measurements seemed warranted.

These were initiated by the NRC-Carleton-Chicago team in the fall of 1974. Since the Chicago cyclotron was by then shut down and dismantled, an arrangement was made to use a similar (and better) cyclotron at the Space Radiation Effects Laboratory (SREL) at Newport News, Virginia. Some preliminary measurements were made in the fall of 1974 and the experiment was completed late in 1975. All the 1974/75 results now seem to be in excellent agreement with the (revised) QED calculations and so add to the stature of the theory at the same time increasing the demand for still better experiments.

The conclusions about QED from muonic atoms depend on the fact that the mass of the muon is very precisely known from independent experiments. The mass of the pion (or pi meson), another important elementary particle which is apparently responsible for the forces that hold nuclei together, is less well known. In an extension of the 1975 measurements of muonic atoms, pionic atom transition energies

were measured with the same apparatus. If we now assume that the QED calculations are reliable, as indicated by the muonic atom results, we can turn the analysis around and extract the mass of the pion. The indications are that, when the analysis is complete, the present uncertainty in the pion mass will be decreased by about a factor of two.

To summarize, this project has led to the observation of several nuclear effects for the first time. More important, it has provided a critical test of QED, one of our most fundamental and most successful physical theories. It will yield a new better value for the mass of one of the most important elementary particles - the pion. It is also an excellent example of highly sophisticated physics being performed by a Canadian group at very modest cost. The provision of free beam-time on U.S. accelerators makes this type of project possible and underlines the value to Canadian science of international cooperation.

## THE DIAMETERS OF QUASARS AND SEYFERT GALAXIES

The discovery in England by Hey (1946) of the radio source Cygnus A had far reaching consequences. Hey rightly deduced that Cygnus A had a small angular size. Later observations have shown that Cygnus A is composed of two sources each about 20 arc seconds in diameter.

Techniques and telescopes rapidly improved during the ensuing years. Soon astronomers were able to deduce that many radio objects could be associated with hot ionized gas in our galaxy or with distant galaxies. A few sources, however, appeared to have very small angular diameters, and were not readily identifiable with any known visible objects.

Radio interferometry, whereby one telescope was connected to another distant one by radio link, enabled astronomers to put an upper limit of less than one arc second on the angular diameter of these objects. The positional accuracy increased until they could be identified with stellar-like very distant galaxies (called quasars, for Quasi-Stellar Radio Sources).

Canadian astronomers, intrigued by the mystery of these very distant galaxies, were convinced that radio interferometry could be released from the restrictions imposed by interconnection. It appeared feasible to eliminate the cable or radio link interconnection by using independent time and frequency generators at each telescope, and by

recording the output separately on magnetic recorders. The magnetic tapes would be brought together later for cross correlation.

Scientists, engineers and astronomers from NRC, DRAO, University of Toronto, and from Queen's University met late in 1965 to explore the independent telescope possibility. Canada had two large radio telescopes separated by 3000 kilometers, one in Algonquin Park and the other at Penticton, B.C. In addition there was a large radar antenna at Prince Albert, Sask. These three instruments were separated in the ratio one to two giving separations between telescopes of 1000, 2000 and 3000 kms. This interferometry technique, if successful, would enable the astronomers to determine if any of the quasars had diameters less than 0.015 seconds of arc. Even at the large distance of the quasars this would represent a very small core to a galaxy. The project was, in a way, daring; such high resolution at radio wavelengths was almost 30 times the best obtainable at visible wavelengths. The existence of radio objects so small that they could be measured by this technique could only be conjectured. Successful measurements of small diameter components, however, could lead to new theories about the dynamics of quasars. So little was known about quasars at this period of time that the prospect of gaining some knowledge about the central core and, perhaps, about the explosive events in this core, presented an exciting challenge.

The experiment appeared to be feasible. The frequency standards had to have a stability such that the data could be integrated for several minutes. That is the signals from each of the recorders could not differ by a cycle in about 10 minutes. The time standard had to provide marks on tape that were reliable to better than a millionth of a second so that the signals could be cross correlated. Highly stable time and frequency standards had been developed for standard time laboratories by two U.S.A. manufacturers. This degree of frequency stability and time accuracy was just available with these commercial units for an experiment at a wavelength of 75 cm. There remained the problem of putting the radio signals on magnetic tape.

The sensitivity of a telescope receiver is proportional to the width of the band of signals received. Most magnetic recorders had a very limited bandwidth and this appeared to be a stumbling block. Recorders having sufficient bandwidth were possible to obtain at considerable cost, but their time stability was somewhat inadequate. The group then learned that some video magnetic tape recorders were being exchanged for new ones by one of Canada's leading T.V. networks. Careful appraisal of the specifications of these recorders convinced the group that the bandwidth and time requirements could be met by these old machines.

Simultaneously with this planning two groups in the U.S.A. were also attacking the problem of independent oscillator-

magnetic tape recording interferometers. Their approach was to record the data digitally and to perform the cross correlation by shifting the data in a large computer, a somewhat different approach than that taken by the Canadian team. Liaison between the three groups was constant and informal, and continued up to the successful detection of signals by this technique. (This liaison continues today on only a slightly diminished level.)

Early in 1967 the Canadian technique was proven with a short baseline separation between a small telescope and the 46 metre diameter telescope at the Algonquin Radio Observatory. Then in May, 1967 successful observations of the quasar 3C273 were obtained from recordings made simultaneously 3000 km apart, at Penticton, B.C. and at the Algonquin Radio Observatory. The Canadian team were pleased to be able to announce this observation just two days later at a joint U.S.A.-Canadian meeting of URSI being held at Ottawa. Within a few weeks the American groups were also successful.

One successful observation may prove a technique, but does not answer the questions posed by the enigmatic behaviour of quasars. Further, a number of different angular resolutions were required to sort out multiple components of some of the quasars. Correspondingly a number of observations were made between the three baselines in Canada. When this did not prove to be sufficient, observations were then made

between the Algonquin Radio Observatory and the 1000 ft. telescope at Arecibo, Puerto Rico, the 140 foot telescope at Green Bank, West Virginia, and the 250 foot telescope at Jodrell Bank.

This series of observations resulted in brightness distributions for 17 quasars and 2 Seyfert galaxies with notes on the structure of 14 other sources. The smallest scale structure recognized from these observations was about 0.005 arcseconds which corresponded to linear dimensions between 20 and 200 parsecs. The size of the emitting region in 3C84, a Seyfert galaxy, appeared to be only about 2 parsecs! By contrast our galaxy has a diameter of about 30,000 parsecs and the nuclear region, albeit poorly defined, has a diameter of about 3000 parsecs.

An interesting feature of these small diameter quasars is that they can have significant intensity variations at centimeter wavelengths on a time scale of weeks. To have such rapid variations they must have diameters of only a few light weeks or months. While much research remained to be undertaken at the wavelength of 75 cm. the Canadian and American groups commenced observations at much shorter wavelengths (typically 2.8 cm) where the intensity variations were large and rapid. Close cooperation exists between all groups involved in long baseline interferometry, and many joint observations are made in order to increase the number of simultaneous baselines.

Long baseline interferometry has a significant influence on theories pertaining to quasars. New results continue to produce surprising interpretations which cause a new flurry of excitement amongst the theoreticians. Canadians have continued to hold a respected place in this field with their contributions.

On April 14, 1971 the work the Canadian and the two American groups in the field of long baseline interferometry was recognized by the American Academy of Arts and Science, Boston, Mass. at its 1513th meeting, by awarding the Rumford Medal jointly to 9 Canadians and 12 Americans. The Academy was founded in 1779 for the "cultivation and promotion of Arts and Sciences." In 1796 Count Rumford donated a sum of money to be used for a medal to the "author of the most important discovery or useful improvement......" Fewer than 75 awards of the Rumford Medal have been made in the intervening 180 years. In 1971 the Academy broke from its tradition of an award to a single recipient to give the award to the three teams of researchers. It is a matter of interest that the only other Canadian award was made in 1930 to Dr. J.S. Plaskett of the Dominion Astrophysical Observatory for his stellar spectrographic researches.

## THE SPECTRUM OF THE WATER ION AND ITS IDENTIFICATION IN THE TAIL OF COMET KOHOUTEK

The spectra of molecular ions and free radicals have been the subject of investigations in the Spectroscopy Laboratory of the Herzberg Institute of Astrophysics for many years. (Prior to the formation of the Institute, the laboratory was part of the Division of Physics). Molecular ions and free radicals are transient species of molecules that are not normally found in the laboratory. However they can be produced under special conditions and many of them undoubtedly exist in the rarefied conditions of outer space. In fact it has been hypothesized (in particular by Herzberg) that many unidentified spectral lines observed in interstellar space are due to molecular ions whose spectra have not yet been seen in the laboratory. In a similar vein Fred L. Whipple in 1950 had postulated that ice was one of the chief constituents of comets but unfortunately this postulate was difficult to test. Neutral water itself does not give off any characteristic radiation that can be detected by means of optical telescopes. It was surmised however that ionized water ($H_2O^+$) should give off optically detectable radiation but no one had succeeded in producing its characteristic spectrum in the laboratory and hence in the case of a comet there would be a question of identification. Many attempts had been made over the years both in our

laboratory and elsewhere to get the spectrum of the water ion but success did not come until 1972.

It was in the summer of 1972 that H. Lew and I. Heiber succeeded in obtaining the optical spectrum of the water ion by bombarding low pressure water vapor with electrons. After a preliminary analysis a note was published early in 1973 giving a brief description of the spectrum and some basic structural parameters of the molecule. Interest in the results was quite high among members of the spectroscopic "fraternity" because of the fundamental importance of water and because this spectrum had been so long in yielding to the efforts of scientists. The interest, however, was strictly from a fundamental point of view, from the point of view of spectroscopic theory and molecular structure. In December 1973, however, the picture changed dramatically. Comet Kohoutek had come close enough to the sun for astronomers to take pictures of its spectrum. Herbig of the Lick Observatory, Santa Cruz, California and Benvenuti and Wurm of the Asiago Observatory, Italy found some spectral lines in the radiation from the tail of Comet Kohoutek that they could not identify. Herzberg and Lew learned of these observations and noticed they corresponded to some of the laboratory lines of the water ion. It was not possible to be absolutely certain that they were due to $H_2O^+$ because only about half a dozen lines were observed and their wavelengths could not be measured accurately. There was a chance of the coincidences being

accidental. However the comet lines did correspond to what one would expect in the laboratory if the water ions were very cold, as they probably were in the comet. This fact made it less likely that the agreement was merely accidental. Accordingly Herzberg and Lew announced that the water ion had been tentatively identified in the tail of Comet Kohoutek and that, if confirmed, the head of the comet was indeed composed of ice as postulated by Whipple. Confirmation came very quickly as Kohoutek approached closer to the sun and more lines were seen by more astronomers. Eventually about 50 lines of $H_2O^+$ were identified in the spectrum of the comet and a joint publication announcing the fact was put out by Herzberg and Lew and three astronomers, Wehinger and Wyckoff (of Wise Observatory, Israel) and Herbig.

The discovery of water in Comet Kohoutek is considered one of the major discoveries to come out of the considerable scientific effort that was expended on this comet. It is felt by astrophysicists that comets are samples of the primordial material of the solar system and any information about parent molecules in comets may throw light on the formation of the solar system.

In summary then, the story of the water ion spectrum represents one of the more recent successes of this laboratory in its program for the study of ions and molecules of possible astrophysical interest. Such studies provide data not only for astronomers but also for physicists and chemists who are interested in basic molecular processes.

## SOMATIC HYBRIDIZATION OF PLANTS

Basic research on the biogenesis of organic compounds in plants was initiated at the Prairie Regional Laboratory in 1955. Radioactive labelled organic compounds were fed to plants to elucidate biosynthetic pathways and the verification was by the isolation of enzymes responsible for the various steps along the route. Yields of enzymes isolated from whole plants were often very low and progress depended on growing uniform plants under controlled conditions. An elegant solution to these problems, conceived around 1963 was to grow the individual cells from plant tissue in the same manner as bacteria and yeasts. Methodology was developed to convert tissue (leaves, stems, roots) into plant cells and grow these in a liquid medium. This successful development opened up a new research area with many potential applications, among which was the growth of plant cells in fermentors to produce valuable compounds such as alkaloids, pharmaceuticals, proteins, amino acids, etc. normally produced by selected plants.

While a limited amount of research was carried out in the above areas, another application was recognized by scientists working on the program. Traditionally, agricultural crops have been improved over centuries by conventional plant breeding and selection involving sexual crossing. This approach is limited to closely related plant species with only a few successes for inter species crosses, e.g. Triticale (wheat

x rye). Steady progress has been made in developing new varieties with improved yield, quality and adaptability to different production areas using world collections of germ plasm (Green Revolution). However, recognition was being given to the law of diminishing returns and around 1969 world authorities including Nobel Prize winner Dr. N. Borlaug suggested that the search for desirable characteristics had nearly exhausted the known potential and advocated the need for the development of a radically new approach.

The scientists working in the plant cell program realized that each cell in a plant contained all the genetic information possessed either by the plant or the seed from which it orginated and proposed a new approach to plant breeding. The proposal was to produce protoplasts (naked plant cells) from plant cells and to fuse the protoplasts to produce hybrid cells which would be cultured to form new hybrid plants. Since this system involved vegetative rather than sexual cells it offered the possibility to make crosses between plants widely separated according to family tree. It was obvious that this was a long-term, high-risk proposal, requiring a great deal of fundamental research and the development of new skills and technologies before the system could be tested and applied to practical problems. However, it had been demonstrated that carrot and tobacco plants could be grown from vegetative tissue and progress had been made in producing hybrids of animal cells.

The successful development of this new concept would extend the transfer of specific factors from one plant to another and permit transfers not possible by the conventional methods. One could visualize the transfer of characters such as the specialized root systems of native plants adapted to an arid or semi-arid region to cultivated crops, the transfer of the nitrogen fixing capability of legumes to cereals and the acquisition of resistance to disease and insects.

The inhouse program has advanced over a decade to the status of a major project. Methodology has been developed to remove the cell walls producing protoplasts ("naked cells") which can be induced to undergo fusion producing hybrid cells. The cell walls can be regenerated to restore the protoplast to the status of a plant cell and these cells can be induced to grow and reproduce. A major breakthrough has been a rapid, efficient technique to increase the incidence of fusion which has produced hybrid cells from more than 15 plant genera. Since the fusion of two plant cells introduces all the genetic characteristics from each cell into the hybrid, an alternate approach is under study to introduce single or limited characteristics in the form of the isolated DNA.

The production of hybrid cells is only the first stage of the system. The second stage is to induce the hybrid cell to grow and regenerate a complete plant. Again, a great deal of basic research and technology is required to provide the necessary background knowledge. Cells from different species

require different environmental conditions and growth hormones for plant regeneration.

To date a number of species have been taken through the cycle from plant cells to protoplasts to plant cells and to regenerated plants.

While the main thrust of the research is being directed to cell fusion, genetic transformation and morphogenesis, the latter has had some practical spin offs. A research contract has been completed to produce disease-free Cassava stock (plants of major importance to developing countries of the tropic and semi-tropic regions) which will permit the establishment of a world collection and exchange of breeding material between continents. A second contract is underway to investigate the potential of the system for another practical application in developing countries. More recently a start has been made to eliminate a virus from the world collection of peas that are the basis for development of improved commercial varieties to develop a protein industry in Canada.

When the program was initiated there were about six groups in the world engaged with cell culture research. The effort in this area has expanded and now encompasses laboratories in more than thirty countries involving more than 1000 scientists. At about the time of inception of the present program the Rockefeller Foundation invited twelve scientists to a conference in Italy to assess the potential of plant tissue culture for crop improvement and recommended support. This has been

followed by a second meeting in 1975 which included plant breeders and scientists from developing countries. On the basis of significant progress, the Rockefeller Foundation endorsed the application of the technology. A representative of the research group at P.R.L. was invited to participate in both meetings. This laboratory has maintained a leading world position and staff have been invited to organize and to participate as main speakers in International Symposia and workshops leading to the establishment of new research groups. At least three major agricultural industries in other countries have set up research groups which is taken as a positive indication of both the potential for this new system and the increasing probability for successful practical achievements. Eleven visiting scientists from other countries have spent periods of three months to a year working at this laboratory with financial support from their organizations. Within the last year scientists from six Canadian research organizations have consulted with the staff on setting up research projects.

While much basic research and technology is still required, the progress towards somatic hybridization of plants has been impressive, has won international recognition for Canada and has moved the original concept from the realm of an idea to a real possibility. The decade of basic research has provided sufficient background to delineate areas and now enables mission oriented research organizations to participate in projects having more specific practical objectives.

## ANTIGENS OF PATHOGENIC BACTERIA

This project was initiated from within a group as a result of a desire to reorient its research in directions that were more relevant from the viewpoints of both scientific challenge and potential usefulness.

The Carbohydrate Section of the Division of Biological Sciences had been studying plant polysaccharides as long-term, directed research related to problems of pulp and paper and agriculture in Canada. It had established itself at the forefront of research in this field, and was regarded as one of the strongest groups in the world in the chemistry of polysaccharides. The results of some 8-10 years of research showed clearly that there were only a limited number of different polysaccharides in plants. There were major differences between polysaccharides in straws, soft woods and hard woods but practically none between those of individual species within each subdivision. When knowledge about plant polysaccharides reached that stage, the members of the Carbohydrate Section felt that the field had been worked out as a scientific challenge and began to consider a reorientation of their research. The criteria used were (a) scientific challenge, (b) relevance to social or economic needs, (c) suitability to NRC, and (d) need for the very strong expertise in polysaccharide chemistry that had been developed in the section. The area of research chosen was bacterial polysaccharides.

Unlike the plant polysaccharides, there were known to be major differences between the polysaccharides of nearly every species of bacteria in which they had been examined. In fact, polysaccharides frequently constitute the only means of distinguishing between serotypes within a species. It was therefore clear that bacterial polysaccharides would present practically an infinite number and variety of difficult, intriguing structural problems. In addition, there was good evidence from work on a few species that polysaccharides were important immunogenic components of bacteria and were the antigens that gave rise to and reacted with antibodies. The problem of explaining the exquisite specificity of the antigen-antibody reaction in terms of structure has been cited as one of the major scientific challenges of modern biochemistry, and the study of bacterial polysaccharide antigens certainly required the expertise in polysaccharide chemistry; thus two of the criteria were met.

Orientation of our work towards the antigens of pathogenic bacteria seemed to provide for both relevance and suitability to NRC. There have been an increasing number of reports of the development of antibiotic resistance in some species of pathogenic bacteria. When one considers the short generation time of bacteria (ca. 20 min), it is not surprising that natural evolution should lead to resistant forms rather quickly. It is questionable whether or not the discovery of new antibiotics will be able to keep pace with the evolution

of resistance. An effective means of counteracting this situation is immunization with the natural antigens of the bacteria. It has been suggested that immunization with isolated, structurally defined antigens, rather than with killed whole bacteria, might provide more effective and safer vaccines. Certainly the use of isolated antigens can give highly specific antisera that are useful as diagnostic reagents. Thus, a program on isolation of bacterial antigens has both social and economic relevance in terms of public health and production of vaccines and diagnostics.

In terms of suitability for NRC, probably the most important consideration is the interdisciplinary expertise required for this work. The strength of polysaccharide chemistry has already been emphasized, but in addition the program requires microbiologists to select and cultivate the bacteria, physical chemists to assist in structure determination, and a well-staffed animal facility for testing antigens and raising antisera. Quite apart from the difficulties of forming such a group in a university milieu (because it would cut across so many departmental lines), the health-safety precautions necessary to work with pathogenic bacteria would be hard to maintain with attendant risks to the student body.

Because there were no facilities at NRC for the safe cultivation of pathogenic bacteria, the program depended initially, and to some extent still does, on collaborations with scientists elsewhere who were able to culture pathogens.

In addition, the group worked on some related but non-pathogenic bacteria to learn techniques and to acquire the requisite expertise in immunochemistry and serological methods.

The pathogenic organisms under study have been, dermatophytic fungi, several Pneumococcal serotypes, Pseudomonas, N. meningitidis and N. gonorrhoeae. Work on the dermatophytic fungi has been completed; structure-serological activity relationships were established for the polysaccharide antigens of some 16 different fungi and the potential usefulness of these compounds as diagnostic agents was demonstrated. Studies of Pneumococcal serotypes are continuing. This bacterium has been showing signs of developing antibiotic resistance and immunization of susceptible segments of the population has been initiated in the U.S.A. There have also been sporadic but severe epidemics in other parts of the world caused by serotypes not previously implicated in the disease. The structures of only a few of the specific polysaccharide antigens are known and methods of isolation and purification are poorly understood. The Pseudomonas are highly infectious bacteria, resistant to antibiotics, and of major significance in hospital-acquired infections and in veterinary medicine. Dr. M.B. Perry, of this group, has shown that the polysaccharide antigens are serotype specific and can be used to generate specific typing sera for diagnostic purposes. A diagnostic services industry (MDS Ltd.) is in process of incorporating this diagnostic system into its services.

N. meningitidis, the causative agent of meningitis, has at least six known serotypes and is not very susceptible to antibiotics. Dr. H.J. Jennings, of this group, has isolated and characterized the polysaccharides of each serotype and shown that they are the serotype-specific antigens. This marks the first time that a complete serotype classification has been explained in terms of polysaccharide structure and the work won for Dr. Jennings the Harrison Prize of the Royal Society of Canada, an award given for a significant advance in fundamental microbiology. During the course of this work Dr. Jennings also found another antigen that was common to all six serotypes. Tests of this antigen in an animal model of the disease developed by Dr. P. Kenny, Laboratory Centre for Disease Control, indicated that it was a protective antigen for all serotypes. Development of this antigen as a possible vaccine for meningitis is being transferred to industry (Frappier Institute) by means of a contract.

Studies on the antigens of N. gonorrhoeae, by Dr. M.B. Perry in collaboration with Dr. B. Diena, Laboratory Centre for Disease Control, have shown that specificity resides in the side chains of lipopolysaccharides and that these are different for different isolates. These results indicate that this bacterium has many strains, a possible explanation for the apparent absence of acquired immunity after exposure. However, the work also showed that the central part of the lipopolysaccharide (i.e. without side chains) was common to

every strain but was specific for the species. Thus, the "core" portion of the lipopolysaccharide was a specific antigen for N. gonorrhoeae and could be used to raise specific antiserum for diagnostic purposes. A diagnostic services industry (MDS Ltd.) has placed its own employees in Dr. Perry's laboratory to learn the technology of lipopolysaccharide isolation and antiserum production with a view to incorporating the specific diagnosis of gonorrhea as one of its services.

This project is an excellent example of the difficulty, if not impossibility, of distinguishing between "applied" and "basic" research in the life sciences. While the project is categorized as "applied", the objective is to discover the relation between the immunological specificity of bacterial antigens and their structure. This involves research into culture methods for bacteria, isolation and purification of antigens, and tests of immunological specificity and activity. All of this must be done before any application is practical. Thus, the work in the project has won an award for "fundamental microbiology" and, at the same time, has attracted the close collaboration and transfer of technology to two commercial companies.

# THE NRC PRIMARY CESIUM CLOCK (CsV)

Although the philosophical meaning of time may represent an almost insoluble problem, the physical generation of time scales by the accumulation of time intervals of almost identical duration, fixed by the physical constants of atoms, has attained a very high level of development during the past 20 years. This very precise construction of time scales can be accomplished by a number of different devices, but the one which has been internationally accepted as providing the most reproducible time scale is the cesium clock.

The most exact cesium clocks, the so-called long beam primary laboratory cesium frequency standards, are large and complex devices several meters in length and weighing a ton or more. Only a few of them have been constructed in the larger national laboratories, and they have all suffered from an inability to operate continuously for longer than a few hours or days.

Smaller, much less exact clocks, about 5% of the size and weight of these large devices, have been extensively developed commercially. The tendency has been to use large groups of these to generate a time scale, on the assumption that the mean clock rate would provide a much more exact and reliable scale than any of the individual clocks. The rate of this mean scale can then be calibrated by means of a long beam primary laboratory standard if one is available. However, despite their smaller size, these commercially produced clocks

are almost as expensive to construct and more expensive to maintain than the larger laboratory instruments.

The new NRC 2.1 meter primary cesium clock (CsV) constitutes the first successful attempt to combine the best features of both types of instruments. Its accuracy equals or exceeds that of the best long beam standards developed by other countries, and for continuous operation the timing error of less than 3 millionths of a second per year is less than that of any other instrument. Except for several very brief interruptions for checks of its operation, it has functioned continuously since May 1, 1975, and has provided the longest and most exact measurement yet made of the rate of the International Atomic Time Scale maintained by the Bureau International de l'Heure. This scale is based on the weighted mean of a total of about 60 commercial atomic clocks located in laboratories and observatories throughout the world, and intercompared by radio methods to precisions of the order of a few ten-millionths of a second.

In addition to these international commitments and contributions, it has been possible, because of the flexibility of the design of CsV and its excellent stability, to carry out a series of cooperative scientific experiments with the Laboratoire de l'Horloge Atomique of the University of Paris under the auspices of the NRC-CNRS cooperative agreement on scientific research.

Development of this new clock has benefitted Canadian industry in at least two ways. Construction of the large stainless steel vacuum tank by Dominion Welding Engineering to NRC specifications has aided in the development of Canadian industrial expertise in the area of high-vacuum technology. Also, CsV as a continuously-operating time standard now makes possible simple, rapid, exact, and inexpensive calibrations of clocks and frequency standards for the industrial community.

From the point of view of economy of operation, initial experience with CsV has demonstrated that (in contrast with time-keeping procedures adopted in other national laboratories which require groups of up to 20 $20,000 commercial clocks) only two or three such clocks will be necessary in future at NRC to bridge the brief periods when CsV is inoperative. In addition, the cost of component parts for CsV was less than twice the cost of present commercial standards. Maintenance costs, because of its readily demountable design, are expected to be negligible.

Possible future benefits to Canadian industry may result from application of the experience gained with CsV to the development of smaller prototype clocks which would have a potential for Canadian manufacture for the international market. Such clocks could satisfy the growing requirement for the very high timing accuracy necessary in navigation and aircraft collision avoidance systems.

Present development work in the United States and Europe is directed toward adapting present commercial atomic clocks for satellite use, and it is possible that the NRC type of standard with its higher accuracy would meet the more stringent requirements of ground control stations.

The achieved accuracy goal of a few millionths of a second per year also has very real practical applications in the area of high-speed digital data transmission where superimposed messages, coded only by timing procedures, must be "unscrambled" at the receiving terminals. Although a primary clock such as CsV would not form part of the data transmission system, monitoring of the digital data rates with respect to it would constitute a valuable service. Indeed, monitoring of the digital data rates of the Bell Data-Route system with respect to CsV has already started, at the request of Bell Canada.

# MECHANISMS OF OUTDOOR SOUND PROPAGATION AND INSULATION OF DWELLINGS AGAINST EXTERNAL NOISES

In recent years the rapidly growing public concern about noise and the large amounts of money involved in either noise control or damage suits have enhanced the need both for a more precise understanding of the mechanism of outdoor sound propagation and also for effective, simple, and economic means of insulating dwellings from outdoor noise sources. The NRC Laboratories have tackled these different, but complementary, problems as two distinct projects.

## Mechanisms of Outdoor Sound Propagation

A comparison of predicted and measured urban noise levels, started in the Division of Physics in 1968, brought to light a serious error in the accepted theory of atmospheric sound absorption: the failure to take into account the vibrational relaxation of the nitrogen molecule. This was shown to be the principal absorption mechanism for frequencies below 1000 Hz which are predominant for aircraft and community noise. (The knowledge crucial to the solution of this practical problem was acquired in an unrelated project of the division's acoustic section: the study of ultrasonic relaxation processes in liquids of interest to chemists.) As a result of this work, the national and international standards concerning the attenuation of airborne sound have been completely revised under NRCL leadership to include the effect of the nitrogen relaxation and are now awaiting official approval.

It soon became apparent that many other aspects of sound propagation outdoors were equally in need of re-examination. For example, it has been shown recently that the finite acoustic impedance of the ground, atmospheric turbulence and land contours are highly important over distances (10 m to 10 km) that are relevant to urban planning. Our current picture includes a protective acoustic shadow zone near the ground that at times is almost ubiquitous but which can be easily lost with poor acoustic design and under adverse meteorological conditions.

The quantitative influence of finite ground impedance and the effects of weather and topography have been demonstrated in a study of the noise levels around Vancouver Airport undertaken for the Department of the Environment, which is intended to serve as a model for use elsewhere. This showed explicitly, for the first time, that noise levels were predicted to be higher for listeners on hillsides than on flat land; this finding was in good accord with the complaint structure of residents in these locations. This improved correlation between theory and complaint patterns should lead to increased acceptance of the validity of environmental impact forecasts for new or modified use of a highway, airport, factory, etc.

The mechanisms of sound propagation which determine the penetration of sound into the community are also of basic concern in the formulation of, and the testing of conformity to, legislation of noise limits for individual motor vehicles.

Thus the impedance of the ground (snow) surface has been found to exert a major influence on the levels of noise measured from snowmobiles during standard tests, and a study for the Ministry of Transport has demonstrated the effect of atmospheric fluctuations of wind and temperature on the sound levels measured using the standard test procedure for road vehicles.

Insulation of Dwellings against Outdoor Noise Sources

Around every major airport there is an intermediate zone where outdoor noise is tolerable, but where special construction is needed to bring indoor noise down to acceptable values for sleeping and leisure-time activities. To delineate this intermediate zone and to devise practical rules for dwelling construction within it, a joint project was organized with the Central Mortgage and Housing Corporation and Transport Canada. Noise exposure forecasts, based on currently used prediction methods, were provided by the Ministry of Transport. The role of the Division of Building Research was to devise simple rules for defining the required sound insulation and to provide a "catalogue" of adequate constructions for various noise zones.

The first edition of these guidelines, published in 1972, was based mainly on experience with indoor sound insulation problems, and it was recognized that the detailed pattern of incidence of aircraft noise on the exterior of a building was not accurately known; nor was the performance

of some external elements of buildings such as windows, doors and roofs. These points have since been investigated in an experimental building provided by CMHC on an approach path to Ottawa airport: subsidiary laboratory tests were also done to provide a link with standard sound insulation tests, and hence a continuing basis for assessment of new building components. In terms of building construction, the results involve mainly the intelligent use of existing technology with emphasis on the performance of windows. One consequential requirement is alternative means of ventilation or air conditioning. The extra cost per dwelling unit in high noise areas is estimated to be between two and three thousand dollars. For directionally defined sound sources, such as traffic noises, the guidelines take account of optimum orientation and internal planning of the building, thus leading to the most economical way of achieving an acceptable indoor noise environment. These further results have been incorporated in a revision of the CMHC guidelines for aircraft noise, and similar guidelines for land use near major roadways and railways.

In summary, the outcome of these related projects has been the reliable prediction of noise levels that correlate well with the listening experience of the public under varied topographical and meteorological conditions, and the provision of a firm basis for standards and regulations promulgated by

government agencies. In addition to outdoor noise considerations, guidelines indicate the most effective and economical ways of providing sufficient sound insulation to give acceptable indoor living conditions.

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## DURABILITY OF BUILDING MATERIALS

Canada suffers a major economic loss every year in the repair and maintenance of buildings. Currently it is estimated that the annual cost of repair and maintenance is about $5 billion, 25 percent of the cost of new construction itself. Deterioration of protective coatings from pollution alone is estimated to amount to about $100 million annually. Deterioration of even the basic building materials, concrete, brick, stucco, etc., continues to occur despite the fact that these have been used for hundreds of years. The inability to predict such failures and thus avoid them can be attributed to the limited knowledge of the basic nature of the materials and the lack of understanding of the various processes involved in deterioration.

It was recognized in the Division of Building Research that improvements in the durability of building materials required a concentrated effort by an interdisciplinary group concerned primarily with the basic factors affecting their

performance. This required the development of specialized scientific expertise committed to long-range studies of the processes of deterioration.

It was recognized that water plays an important part in most deterioration processes such as corrosion of metals, freezing destruction in porous materials, and the weathering of organic materials. It is also an agent causing instability in materials due to swelling on wetting and shrinkage on drying. Hence, much research was devoted to the study of the interaction of water with materials.

Cracking of materials due to drying shrinkage is a common experience. The process of dimensional change due to wetting and drying of porous materials, such as hardened cement in concrete, was investigated very throughly. It was discovered that part of the water lost in drying was in fact contained in the structure of the layered system and accounted for the large shrinkage. This information led to the formulation of a new model of hydrated cement serving as a tool for understanding and predicting the behaviour of this material.

Destruction of concrete, brick and stone by frost action in the severe climate of Canada is well known to all Canadians; and yet this process was not understood. Basic research on this question for several years yielded a significant level of understanding which showed that under freezing conditions a piece of concrete behaves in much the same manner as a piece of carrot or potato. There is a

definite link between cryoinjury (the destruction of biological material during freezing) and damage that can occur when porous inorganic materials containing water are frozen. This understanding of the freezing process is now being exploited to produce a more durable concrete, for which an application for a patent is being made. A method has also been developed for evaluating brick for resistance to freezing damage which is now being considered by the industry as a quality control in the manufacture of brick.

Although some organic-based materials, such as wood, bituminous materials and various protective coatings, have a long history of use in construction, several of these materials, e.g., plastics, are of very recent origin. Many problems experienced with these materials are related to the lack of knowledge of their basic properties on the one hand, and lack of understanding of the process of deterioration on the other. This situation is similar to that described above in connection with inorganic building materials. Concern about the inability to predict long-term performance of a given paint from short-term tests or from measurements of its basic properties has prompted studies to provide the basis for such prediction. Weather factors, such as solar radiation, duration of surface moisture and surface temperature, are being measured along with degradation of various materials to provide an understanding of the degradation mechanisms and a more rational basis for accelerated tests.

In this connection, a recent study has revealed the mechanism of failure of glass-reinforced polyester sheet material, now used in exterior cladding and autobodies, when exposed to outdoor weathering. Two processes were identified: one involves a fatique failure of the glass fiber to polyester bond, induced by cycles of temperature and moisture, the other involves surface micro-cracking of the resin induced by ultra-violet light in solar radiation. This knowledge will help manufacturers to evaluate quickly any newly developed material in this class from the standpoint of long-term performance.

The expertise acquired to develop knowledge of the materials, and their behaviour under various conditions of service, can be exploited in the development of more durable materials for severe conditions of use, such as repair of materials. Patent application is being explored for recent development of a repair material for pot-holes involving a composite made from fiber-reinforced asphalt-sulphur composition.

The cases cited above are contributions to science-based knowledge that have not only been recognized by the science community, but have also resulted in advances in the technology of manufacture, testing, and evaluation of the performance of building materials. This contribution is certain to result in a significant economic benefit from reduced cost of repair and maintenance of building materials. Much more can be achieved by exploiting the existing core of expertise on building materials.

## COLD REGIONS ENGINEERING RESEARCH

When the Division of Building Research was established in 1947 it was recognized that there was a need for engineering information on permafrost, ice, and snow for construction and development activity in northern Canada. Research on these materials was initiated with the objectives of developing the knowledge base required for sound engineering practice and a source of expertise that could respond to requests for information concerning solutions to northern engineering problems. Particular attention has been given to field investigations of the performance of foundations and structures in permafrost, the distribution and characteristics of permafrost, strength and deformation properties of ice and snow, field investigations of the bearing capacity of ice covers and the effect of ice on structures, and the characteristics of avalanche and avalanche defence systems.

With the discovery of petroleum in Alaska, there was a sudden increase in demand for information on the properties and characteristics of permafrost. The permafrost research group of the Division of Building Research was, initially, the only activity of its kind in Canada that was able to respond to this demand. Although the Division had only a total of three professionals working in this problem area, they were able to draw on more than twenty years of investigations to provide very significant and useful guidance and advice to private companies and government agencies that now

had to learn to construct and operate on a much larger scale in the north.

One example is assistance given to Mackenzie Valley Pipeline Research Limited in the planning, instrumentation, observation, and analysis of a test facility to evaluate the performance of a hot oil pipeline near Inuvik, NWT. The Division provided space and technical supervision to the company for the development of techniques for measuring the properties of thawing permafrost, and for carrying out measurements required for the analysis of the observations. Through support provided by the company, equipment and procedures were developed for measuring thermal conductivity of frozen soils both in the laboratory and in the field. The capability developed in this project has since been used to measure (for the Institute for Guided Transport at Queen's University) the thermal conductivity of frozen ores and coal. This information was required by the Institute for an investigation carried out for industry on freezing of ores and coal in railway cars. Similar measurements of the thermal conductivity of frozen and thawed soils were made for the Department of Indian Affairs and Northern Development in connection with the design of the Mackenzie Highway.

A second example is the role the Division has played in an inter-departmental investigation of the use of insulation for preserving permafrost beneath roads in the north. In many northern areas there is a severe shortage of suitable

fill material for highway construction, particularly when the fill must be of sufficient thickness to prevent the thawing of underlaying permafrost. Insulation may be one practical solution to the problem. The Division designed an appropriate field test program, developed the instrumentation required, supervised the installation of the instrumentation and construction of the test road, and is presently making the observations of performance and analyzing the results.

In the winter of 1973-1974, Panarctic Limited submitted an application to the Department of Indian Affairs and Northern Development for permission to construct an offshore ice platform for drilling a delineation well near Melville Island, NWT. The Department asked the Division to assist it in checking out the design and in carrying out the observations necessary to ensure that it performed in a safe manner. The Division was able to provide this assistance based on the expertise that it had acquired. It performed a similar service for a second well in the winter of 1974-1975. Through this participation the Division was able to ensure that the experience gained by Panarctic Limited and its consultants on this activity was properly recorded, in addition to making a significant contribution to the development of design procedures for this unusual use of ice covers. It is estimated by Panarctic Limited that being able to drill wells from ice platforms has brought about the saving of

several millions of dollars. Three wells are to be drilled from ice platforms in the winter of 1975-1976. The technique has now been sufficiently developed that future monitoring activity can be carried out on a more routine basis by departmental and industrial technicians.

In 1974 the Division was asked by the Department of Public Works and the Ministry of Transport to assist in evaluating the design and performance of a wharf constructed for a mining development in a joint government-industry project at Strathcona Sound on northern Baffin Island. The Division developed and installed instrumentation to monitor ice pressures and other parameters at this structure and is analyzing the observations being made. The results of this study will provide much needed information relevant to the establishment of shipping facilities in the far north.

The Division of Building Research is recognized, both nationally and internationally, as a prime source of information and expertise on not only applied but also basic research aspects of cold regions engineering. It has gained this reputation as a result of studies (conducted in the laboratory and the field over the past twenty-five years) to provide basic information on the properties of frozen ground, snow and ice, and on the occurrence and distribution of permafrost. Staff members have also organized or participated in many national and international symposia and conferences dealing with these topics and applied northern engineering.

It is anticipated that expenditure by government and industry on the development of national resources and the associated necessary infrastructure will exceed several billions of dollars in the next few years. Information obtained and disseminated by the Division will help to improve the design and construction process. Benefits gained by constructing in a proper and safe manner will be reflected economically and socially in providing the desired quality of life in this region of Canada.

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## FIRE RESEARCH ACTIVITIES

The degree of fire protection in buildings is in general determined by the provisions contained in building and fire codes. The construction industry is obviously affected by such provisions. To assist those concerned with building fire protection, the Division of Building Research operates a well equipped fire research facility. The staff of this facility has over the years developed expertise in many areas of fire protection. These include the fire resistance of building materials and assemblies of building materials, surface flammability of lining materials, gaseous products produced when materials burn, fire behaviour in compartments, and smoke movement and its control. Advice is available on a continuing basis to authorities concerned with the development of fire safety regulations and to the construction industry.

The problem created by the vertical movement of smoke through a building during a fire was brought dramatically to the attention of the Committee on the National Building Code by a fire in the ground floor restaurant of a tall Montreal hotel in which smoke moved rapidly into upper floors by way of elevator shafts and stair shafts.

As this event could be readily understood in the light of studies carried out on stack effect which produces other problems in buildings, a joint project was introduced including members of both the Fire Section and the Environmental Section of the Division of Building Research.

Provisions intended to improve safety to occupants by controlling, among other things, smoke movement, were introduced into the National Building Code. The Division of Building Research participated in the preparation of a supplementary document to the National Building Code which includes typical fire safety systems that can be incorporated in a building in order to meet the requirements of the Code. Designers and building inspectors have had frequent meetings with staff members in order to discuss the implementation of these measures in proposed buildings and visits have been made to resulting completed buildings to study the effect of the measures.

The National Building Code describes fire performance of building elements by reference to certain standard fire

tests. The Division of Building Research has provided needed information by conducting standard fire tests and by the study of test reports from other sources. A companion document to the National Building Code, Supplement No. 2 Fire Performance Ratings, has been developed by the code committees with the technical assistance of the Fire Section. This provides ratings for a wide range of generic materials and assemblies that are covered by standard specifications.

Tests carried out at the Division of Building Research have improved the information base, with the result that ratings have been refined and economies achieved. For example, a study of the factors in the fire performance of reinforced concrete columns carried out jointly by the Fire Section and Building Structures Section has resulted in improved understanding of the behaviour of these columns in fire. The performance of concrete and hollow concrete masonry walls was also the subject of an intensive study which allowed more precise figures with resultant economies in materials to be obtained for use in Supplement No. 2.

The advent of new materials or variations of materials has created hazards that have called for new tests for their evaluation. Towards the end of the last decade, incidents were reported in which carpets played a major role. In the extreme, fire propagated rapidly along corridors in which carpet was

the only combustible material present. The hazard was judged similar to that assessed by the ASTM E84 Tunnel Test for ceiling and wall lining materials. It was found that for many materials the rate of propagation was of the same order whether a specimen was mounted on the ceiling or on the floor. It was therefore concluded that the ASTM E84 Tunnel Test was also valid for floor coverings. The test was first incorporated into the National Building Code and then adopted as a CSA (now ULC) standard.

The use of plastic light diffusers and ceiling lighting panels poses a hazard because the most suitable materials are quite highly flammable. It is submitted by manufacturers that as generally used, the diffusers and panels would fall out of their ceiling mountings before contributing to a fire and that the same material burning on the floor would present a reduced hazard. The tunnel used in the ASTM E84 Test was adopted to provide a "drop-out" test indicating whether or not a product would fall out before becoming involved in fire. The test has been referenced in the National Building Code and it is likely to become a national standard.

The appearance of plastic foam in the building field has created problems regarding the assessment of its flammability. Hitherto, materials described as highly flammable have shown both rapid and extensive fire propagation. Unfortunately, the

relationship between rapidity and extent of travel is not the same for both plastic foams and more conventional materials. This has created fundamental difficulties in the assessment of the hazard which will require considerable study before the problem can be resolved. The Division of Building Research is currently conducting appropriate studies and is cooperating with the U.S. National Bureau of Standards with regard to some aspects of the problem. In the meantime, many authorities have recommended that foam plastic be covered and the National Building Code has adopted this policy. To implement these provisions, standards for covering foams and for assessing the hazards of foams within cavities must be developed. The Division of Building Research has developed two tests in this field that are currently being considered by the ULC Fire Test Committee.

Industrial Fellowships

The Division of Building Research has developed an arrangement whereby an industry or an industrial association can support a Research Fellow working in the Division's laboratories. Industry provides the salary for the Fellow and the Division provides technical and administrative support and the use of its facilities. Very successful programs have been carried out, for example, with the National Concrete Producers Association and the Canadian Institute for Steel Construction.

The National Concrete Producers Association fellowship program resulted in a large number of fire endurance tests of hollow concrete masonry. This enabled improved ratings to be developed for Supplement No. 2 of the National Building Code and the possibility of taking into account several significant variables that previously had been neglected. Changes due to the addition of sand to lightweight aggregate concrete, the filling of hollow cores and the addition of gypsum board over the surface of concrete block walls were measured and rated.

Fire endurance tests carried out under the Steel Fellowship program have resulted in improvements in some ratings in Supplement No. 2 relating to membrane protection of steel floors and beams. Tests and study of the performance in fire of steel columns resulted in the development of formulae relating mass of steel and thickness of protective covering to fire endurance. This has introduced economies in fire protection of steel columns. In addition, the combination of sheet steel and an insulating lining has been accepted as a means of obtaining a desired fire resistance. These have the advantage of dry installation, the possibility of prefabrication and of providing some protection against physical damage.

Over 75% of new residential construction in Canada is influenced by the National Building Code. This activity has an annual value of about 12 billion dollars. It is clear that results of research that bring about significant changes

in the Code, particularly those that result in reduced cost of construction, will have a desirable beneficial effect on both safety and the national economy.

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## DEVELOPMENT OF TUBULAR MEMBRANE TECHNOLOGY FOR REVERSE OSMOSIS APPLICATIONS

Reverse osmosis is a general process for the separation of substances in solution. The process consists simply in letting a solution flow under pressure through an appropriate porous membrane; depending on the membrane material and its surface porosity, the solute is partly or completely retained on the upstream side of the membrane, yielding a membrane-permeated product enriched in the solvent. The process has become practically significant since the development in 1960 of a successful technique for making highly productive porous cellulose acetate membranes for water desalination. In view of the obvious potential of reverse osmosis for many industrial applications, a program of basic and applied research was started in 1961 in the Division of Chemistry to explore reverse osmosis in all its aspects.

This research program was concerned with the factors governing reverse osmosis separations, choice of membrane materials and membrane-making conditions, and the development of appropriate technology for bringing reverse osmosis into industrial practice. This program has already opened a

series of possible practical applications for the reverse osmosis process. It has been demonstrated that the process is applicable to the entire field of domestic and industrial water treatment including water purification, water pollution control, water renovation and reuse, and waste recover. The process is also applicable to:

- The production of ultrapure water needed for electronic industries,
- The concentration and fractionation of heat-sensitive solutions involved in food-processing and pharmaceutical industries,
- Hydrocarbon separations and fractionations involved in petroleum industries,
- Gas separations involved in the recovery of helium from natural gas,
- The control of atmospheric air pollution resulting from industrial gaseous effluents.

Continuation of this research program is expected to result in the evolution of appropriate practical membrane systems for all the above applications of reverse osmosis, and also make a significant contribution to many other areas of science, engineering, and medicine.

Porous cellulose acetate membranes are particularly effective for many water treatment applications. For this reason, the above class of membranes were studied in detail.

As a result of these studies, the major factors controlling the surface pore structure of membranes during the process of making them were recognized. Consequently, several improvements in the technique of making flat cellulose acetate membranes were accomplished, yielding more productive and more uniform membranes for practical use. These improvements were incorporated in a patent application in 1970. Immediately thereafter, work started on the development of a similar technique for making seamless tubular cellulose acetate membranes. The interest in tubular membranes arose from the fact that they could be cleaned easily and frequently without damage to the membrane surface - a fact of considerable practical importance in the choice of reverse osmosis for the treatment of industrial waste waters contaminated with suspended and colloidal impurities which tend to deposit on the membrane surface. By early 1972, a successful technique for making tubular cellulose acetate membranes was developed, and a patent application for this technique was filed.

During 1971-72, Electrohome Ltd., Kitchener, Ontario, was considering new ventures as part of their diversification program. The potentialities of reverse osmosis for desalting water for their humidifiers, and for general industrial water pollution control attracted their attention. At that time there was no company in Canada engaged in reverse osmosis technology. Therefore Electrohome became seriously interested in the field of reverse osmosis equipment manufacture for

various industrial applications. They were planning to obtain cellulose acetate membranes for their equipments from a foreign source which however soon became unavailable. It was at this time (Fall of 1972) that they came to know of NRC developments in membrane technology at one of the trade shows of Canadian Patents and Development Limited. An Electrohome representative visited NRC Laboratories for a few days after the show to learn more about the details of NRC technology for making tubular cellulose acetate membranes. As a result of this visit, Electrohome decided to enter the field of reverse osmosis, use NRC technology for making tubular membranes, and manufacture their own membranes and modules for reverse osmosis applications. By December 1972, Electrohome had established a separate department for the reverse osmosis venture, and assembled the necessary staff to get the program started.

Active cooperation between NRC and Electrohome in the field of reverse osmosis began in January 1973. The tubular membrane technology was transferred to Electrohome laboratories early in 1973. With frequent consultation with NRC staff, and assisted by NRC's Industrial Research Assistance Program, Electrohome developed their own modules and expertise in membarane manufacture, equipment design, construction, operation, and maintenance. After the necessary laboratory and field experience with different industrial waste waters, they entered into a formal licensing agreement with Canadian Patents and

Development Limited, and began to market their own tubular reverse osmosis membrane modules and auxiliary equipments for industrial water pollution control applications.

In December 1974, Electrohome expanded their staff and facilities and established a full division for reverse osmosis engineering. Their equipment is already in the market for the treatment of radioactive wastes, nickel plating wastes, and oily waste waters. They also have their equipment under long-term field tests for the treatment of waste water effluents from food-processing industries.

Early in 1975, Electrohome felt the need for increasing the production efficiency of their membrane-making unit. In response to this need, NRC developed a new technology which increased the production efficiency of the membrane-making unit 5 to 10 fold compared to the earlier technique. After a preliminary disclosure to Canadian Patents and Development Limited, the new technolgy was put into operation at Electrohome in December 1975. Electrohome is currently using this new technology for their membrane manufacture.

The reverse osmosis venture is growing at Electrohome. Building on this venture, Electrohome expects to get firmly established in all aspects of domestic and industrial water treatment within the next 5 years.

In terms of water treatment application alone, the social relevance of reverse osmosis is second to none. In terms of all its industrial potentialities, reverse osmosis research can be expected to yield significant economic benefits to Canada.

## POLICE SCIENCE AND POLICE EQUIPMENT

The National Research Council has a long record of projects with legal implications, carried out in association with police forces and government agencies. These have included consultations and examinations; research projects carried out on request; the preparation of codes, regulations, or legislation; and accident investigations. The time involved has ranged from the duration of a telephone call to approximately 15 man-years for the DC-8 crash at Ste. Thérèse on 29 November 1963. In March 1969 the Canadian Association of Chiefs of Police (CACP), in their Brief to the Senate Special Committee on Science Policy, recommended that "an appropriately constituted Canadian council of law enforcement science and technology be constituted as a matter of national urgency." The Science Council of Canada, in its Annual Report for 1969-70, supported the CACP and said that "As an example of an urban problem which gets little attention from science and technology, there is the problem of administering law in our cities. There is much modern science and technology available which is not being effectively used in support of law enforcement mechanisms and in the prevention of crime".

These recommendations encouraged NRC to start studies directed towards assisting law enforcement in general and police forces in particular. The work has included two closely related projects, both carried out in close association

with the CACP and its member forces.

In the Division of Electrical Engineering, a group of scientists is carrying out research on the allocation of patrol cars. Since its formation, the group has worked with four police forces from different parts of Canada and has gained an international reputation. The practical object of the research is to optimize the allocation of radio patrol cars both throughout the area they cover and by time of day. Since 24-hour operation of a single car may cost over $100,000 per year, the potential savings are great. Also since the chances of catching certain offenders depend on the speed with which an officer can reach the scene, the proper positioning of patrol cars may improve arrest rates. The group's main research tool is the computer, which is used in simulations of the police force's patrol operations. It allows experiments to be done rapidly without the expense or morale problems of changing a real force many times. The group has also obtained results of practical interest, including the probability distributions of patrol car speed and of the rate of calls for service at police headquarters. Work planned includes the display of police information on maps on a TV screen aided by computer calculations. This should be valuable both for daily operations and executive planning.

The second project concerns police equipment. Much of the equipment purchased by police departments was originally designed for purposes other than law enforcement, and is

accepted only because there is no other choice. Few police forces are large enough to employ specialists in product evaluation, and few standards or specifications have been prepared. In order to remedy this situation, representatives of the NRC and the CACP, assisted by representatives from the Ministry of the Solicitor General, the Department of Justice and the Department of National Defence, set up a secretariat within NRC and organized the NRC-CACP Technical Liaison Committee on Police Equipment (TLC). At the same time, formal liaison was established between NRC and the U.S. National Bureau of Standards' new Law Enforcement Standards Laboratory. The TLC has held meetings since January 1975 and has undertaken to write specifications and guidelines on police equipment for publication and distribution to Canadian police forces. The first edition of the Procurement Guide for Police Equipment - a Compendium of Specifications - will be released in January 1976 and revisions are planned every six months.

The work of the TLC is largely carried out through Technical Sections. These cover the following fields: burglar and security systems; chemicals; communications systems; dress; electronic devices; emergency and rescue equipment; firearms; investigational equipment; personnel protection; training equipment; working aids; and vehicles. Experts from NRC, police forces, and other agencies are included in the Technical Sections. Task groups for some studies have been

set up, and needed research or testing is carried out by NRC. The design of future equipment should therefore be greatly aided by the TLC.

While the police science and police equipment projects are relatively new they have already produced substantial benefits. The patrol allocation project has not only resulted in improved allocation but has led to the production of mapping and information systems in daily use by police forces. The TLC has given advice on faulty equipment, for example on recently developed bullet-proof clothing, which has saved not only money but possibly lives as well. Benefits may be expected to increase in the future.

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## MIRAMICHI CHANNEL (N.B.) STUDY

In 1973 the governments of Canada and New Brunswick received the report of the Northeast New Brunswick Transportation Study by Lalonde, Valois, Lamarre, Valois and Associates, which contained the recommendation that "in-depth hydraulic and ecological studies be made of the technical aspect of dredging the Miramichi River to 26 ft." Increasing the depth of the Miramichi Channel from its present 20 ft to 26 ft would significantly affect the future of the ports of Chatham and Newcastle. The cost of shipping by sea through these two ports is high because of the limited draft, presently available in the

Miramichi Channel, necessitating either the use of very small vessels, or only partly loaded larger vessels. The two ports handle close to 1,000,000 tons of cargo annually.

As a direct result of the above recommendations, an intergovernmental-interdepartmental steering committee was set up in 1974 and subsequently the "Canada - New Brunswick Subsidiary Agreement - Miramichi Channel Study" was signed on February 17, 1975 by the Minister of Regional Economic Expansion and the Premier of New Brunswick. The following departments are participating in the Miramichi Study:

- Federal: National Research Council of Canada
  Transport Canada
  Department of Public Works
  Department of Regional Economic Expansion
  Environment Canada
- Provincial: Department of Economic Growth
  Department of Tourism and Environment

The three main components of the study are:

- a hydrographic survey of the Miramichi Estuary,
- a large hydraulic model of the Miramichi Estuary,
- an environmental impact study.

The direct cost of the study, estimated at $600,000., is financed collectively by the participating departments and agencies. All indirect costs (labour and overhead) are absorbed by each department.

The involvement of private industry in the study has been substantial; the hydrographic survey of the estuary was carried out by Comdev Marine, a $300,000 contract, financed by the Department of Regional Economic Expansion, administered by the Department of Supply and Services and supervised by Environment Canada and the National Research Council of Canada. The environmental impact study is being carried out through small contracts to several companies, with a total contract price of $100,000 paid by the Department of Public Works, Transport Canada, and the Province. The entire study is managed by a private consultant, under contract with the Department of Public Works.

The National Research Council of Canada's share of the study is estimated at $200,000. The direct cost of the model study, $80,000 is paid by Transport Canada.

The model study is being done at the National Research Council of Canada because of its unique facilities and expertise. This large salt water model (100 ft wide and over 300 ft long, to a scale of 1:800 could be built and operated within a relatively short time span. The project will be completed by July, 1976.

The model study will determine the engineering and ecological feasibility of deepening the Miramichi Navigation Channel to 26 ft. It will define the location of spoil grounds to dispose of the dredged material in such a way as

to minimize future maintenance dredging and to protect the ecology of this estuary, where the fishing industry is of vital importance.

With the increased draft, the ports of Chatham and Newcastle will be expanded, to accommodate larger vessels (reconstruction estimated at 4 million dollars) and new facilities, including a paper shed of 27,000 sq. ft will be built.

The economic and social benefits of this study are obvious. If the channel had been dredged without a model study, it could have led to serious damage to the ecology and therefore the fishing industry and future maintenance dredging could not have been minimized.

While the study is very much concerned with applied research, there is a number of basic research problems. First of all there is the problem of modelling salinity mixing in estuaries, which is becoming of interest not only in Canada but in many other countries. This is only the second salinity model study in Canada, both done at NRC. Secondly, the sand in this estuary is supplied by littoral drift along the New Brunswick coastline, brought into the estuary by the tidal currents. The theory of sediment transport by littoral drift currents is still in its infancy and there is great interest in this type of project, where predictions based on calculations and model studies can be verified in the future.

## INDUSTRIAL AERODYNAMICS

The extensive wind tunnel facilities at the National Research Council were originally developed to provide the tools of aerodynamics research and development for the Canadian aircraft industry. This policy dictated the sizes and types of wind tunnels, and required that they be supported by elaborate instrumentaiton, data processing systems and a complement of professional expertise. The investigative capability concentrated in these facilities is unequalled elsewhere in Canada and by few other establishments in the world. While the NRC wind tunnels continue to be heavily used, on a contractual basis, by the domestic aircraft companies, they have attracted more and more use by American, Swedish, U.K., and other foreign aircraft companies. A by-product of these activities has been a healthy exchange of research information at both a national and international level.

Over the past ten years it has been possible to expand the role of the low speed tunnels by undertaking a program of research on problems that arise in other branches of engineering. In the transmission of electric power for example, overhead cables continue to be plagued by a variety of wind-induced vibration problems which may lead to black-outs and costly line deterioration or failure. The trend towards very high voltages for long transmission lines has led to the need for bundled conductor arrays which minimize

Corona discharge but which have introduced new aerodynamically-based vibration phenomena. The NRC facilities are well-suited for investigating the problem, and studies have been done, under contract, for Canadian and American manufacturers and power utility companies. In particular, a fundamental investigation was carried out collaboratively with the Hydro-Quebec research establishment (IREQ) that has identified conceptual solutions to the problem. The ideas developed in the laboratory are being confirmed on a full scale test line facility established by IREQ on the Magdalen Islands that is the foremost of its kind in the world. The research and development program is focussed on the transmission line design for the James Bay power development project.

The use of high strength steels, welded construction and other advances in structural engineering have led to relatively flexible, lightly-damped structures that are more responsive to wind action. It has become common practice to carry out wind tunnel investigations of unusually tall or slender buildings, and intermediate and long span bridges of modern design. At NRC, techniques have been developed for simulating in the wind tunnel the properties of gustiness and wind shear that are characteristic of the natural wind, thus providing the correct environment for investigations of complex civil engineering structures. Currently an investigation for the British Columbia government of the proposed widened version of the Lions' Gate Bridge is

underway. This program includes a 1:100 scale full aero-elastic model for study in the 30 ft. × 30 ft. wind tunnel. A variety of modern Canadian and American bridges have also been studied. Design modifications that improve or stabilize the behaviour of the bridge result from the investigations.

The arrays of tall, slender pressure vessels that are used in Canadian heavy water plants are susceptible to problems of aerodynamic instability. Designers became aware of this effect when at one early plant, vibration amplitudes approached overturning limits and the tower foundations were damaged. Investigations at NRC have identified the phenomenon and led to appropriate techniques for suppressing the motion.

Studies of buildings are now routinely carried out on behalf of architects and engineers to assess wind-induced motion, wind loads, and surface pressures for facade and glass design. As well, it is frequently required to examine the possibility of adverse changes in the ground level wind environment that may arise as a result of the presence of a new major building. It is well established that the urban environment can be degraded in this way and there are examples in many Canadian cities. Methods have been developed for assessing and minimizing the effects of new structures.

Peripheral to the aerodynamic investigations has been the development of simple, lightweight dynamic vibration absorbers. Passive motion dampers of this sort are now

installed on an array of towers, on structural components of a large arch bridge on Cape Breton Island, and are proposed, as a result of investigations at NRC, for the solution of a costly vibration problem of a major new American bridge, and for a tall elevator tower at the La Prade heavy water plant now under construction.

The energy crisis and higher fuel prices have placed increasing pressure on highway truck transportation companies to economize on fuel in order to maintain their competitive positions. At highway speeds, aerodynamic forces on the vehicles account for a major part of fuel usage. A thorough investigation of basic design features and the effectiveness of commercially available aerodynamic add-on devices is now underway using 1:10 scale models of conventional tractor-trailer configurations. Also, in the field of vehicle design, considerable effort has been put into the aerodynamics of highway snow plows, snowmobiles and motorcycles on behalf of Canadian organizations.

In the design of ships it is important to ensure that there is an effective smoke stack that leaves the effluent well clear of the ship and prevents reingestion into ship ventilation systems and engine intakes, and eliminates the possibility of corrosive action by the gases on sensitive equipment. Wind tunnel studies to assess stack performance and to measure aerodynamic forces on the hull and superstructure

are carried out for Canadian designed naval ships, ice breakers, car ferries and other vessels.

In some of the areas that have been discussed, NRC and other Canadian institutions and universities have been in the forefront of technological advance and have provided international leadership. One example is the research at the University of Western Ontario into the response of tall buildings to wind turbulence. Another, the investigations by Ontario Hydro, Hydro-Quebec, and NRC into the aerodynamics of power cables. Research and development in all these areas and others should continue to provide industrial support of a specialized character and lead to more effective and more economical design.

These activities at NRC have been deliberately increased over the past ten years, not only in the volume of effort, but in the range of technology to which the work relates. Much of this work is in support of industry and is aimed at explicit problems, but it is found in many projects that basic or novel contributions to the technology are required. Publication of the results of the work appears in professional and scientific journals and proceedings. In addition to the experimental role, a specialized consultative capability has been created which is called on regularly to serve Canadian industry. The increased use of wind tunnel time for industrial aerodynamics complements the aeronautical usage and ensures optimal utilization of the wind tunnel facilities.

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## IRISH MOSS

Supplies of agar-agar, a gelling agent used in the microbiological, pharmaceutical, and food industries were critical between 1940 and 1946 and an extensive survey was undertaken for alternate sources. The gelling agents in Irish Moss (Chondrus crispus) which grows on rocks in the sub-tidal zones of the Northern Atlantic Ocean were isolated by NRC scientists and their chemical nature determined. Though the gelling agents, the carrageenans, are not suitable as agar substitutes, they do have a number of unique properties that make them useful in the manufacture of a number of food and chemical products. About 80% of the world's supply of Irish Moss is harvested on the Atlantic Coast, principally in P.E.I. and Nova Scotia. In 1974 the landed value of this seaweed was $5.8 million and it is the principal commercial seaweed in Canada. In Japan the annual value of the seaweed industry is about $250 million. The harvesting of commercially important seaweeds is being promoted and regulated by the Fisheries Service (Environment Canada) but resources are limited and conservation is important.

When the Atlantic Regional Laboratory was opened in 1952, little scientific information was available on local marine plants, particularly algae. A long-term research program was initiated and has gradually developed over the years with the object of determining what algae are present

in the coastal waters of the Atlantic Provinces, their reproductive and biochemical processes, genetics, growth, nutrition, and chemistry, that is, of obtaining a background of knowledge on which development work can be based. Much of the early survey work on ecology was done by the Nova Scotia Research Foundation. The Atlantic Regional Laboratory conducts much of its research in collaboration with scientists in universities in the Atlantic region, and with guest workers and scientists from other organizations, including industry.

In 1967 the decision was made to establish a seaweed culture station on the shores of the Atlantic Ocean as a facility for growing marine algae in seawater under controlled conditions for experimental work and as a facility for examining the possibility of developing commercial methods of propagating Irish Moss. Success in the project is based on having a facility with flowing seawater available, on discovering the life cycle of Irish Moss, on determining the chemistry of the carrageenans, on discovering the relationship of the carrageenans to the life cycle of the alga, and the determination of the optimum conditions for growth and for synthesis of carrageenans. The technical success of the method for propagating Irish Moss vegetatively in tanks containing flowing seawater at the Seaweed Culture Station has interested two commercial companies who have established pilot plants and who are carrying out further development work. Commercial propagation of Irish Moss would permit an expansion of present markets and conservation of the natural resource.

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## HIGH-POWER, LARGE-VOLUME, U.V. PRE-IONIZED $CO_2$ LASERS

In 1970, when the first transversely-excited atmospheric pressure (TEA) $CO_2$ laser was reported by Beaulieu,[1] the Laser and Plasma Physics section had already been actively involved in applications of high energy pulsed lasers for a number of years. This activity had developed for two principal reasons: (A) one of the section's continuing experimental programs was concerned with the investigation of plasmas produced by intense laser radiation and (B) ultrashort laser pulses had permitted the development of several new plasma diagnostic techniques with extremely high spatial and temporal resolution. Although much of the NRC work on laser-produced plasmas had been carried out in gases and was of a fundamental nature, the original motivation for this work was the possibility of using lasers to produce high temperature plasmas of thermonuclear interest.

The development of the TEA $CO_2$ laser provided for the first time a practical gas laser capable of generating peak powers in the megawatt range. Furthermore, the active medium was inexpensive, readily available, and could be excited directly with electrical energy. As a result, such lasers were relatively simple to construct and much more efficient (approximately 10%) than solid state lasers.

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[1] A.J. Beaulieu, "Transversely excited atmospheric pressure $CO_2$ lasers", Appl. Phys. Letters 16, 504 (1970)

In common with many other laboratories around the world, NRC constructed their own TEA lasers and began to incorporate them into the experimental program previously carried out with solid state glass lasers. The original TEA laser described by Beaulieu was rapidly followed by a number of double discharge designs which permitted the construction of larger volume $CO_2$ lasers having maximum inter-electrode gaps of about 5 cm. Many laboratories attempted to scale the $CO_2$ laser to even larger apertures and the approaches adopted included the use of high energy electrons to pre-ionize the laser gas.

During 1971 a number of schemes aimed at stabilizing large cross-section, atmospheric pressure, glow discharges were investigated at NRC. By September 1971 a new transverse discharge device with a substantially better performance had been developed. In its original form this device had an interelectrode gap of about 5 cm and permitted the efficient excitation of large volumes of $CO_2$, $N_2$, and He gas mixtures at atmospheric pressure and with a high concentration ($\sim$ 30%) of $CO_2$. Stabilization of the discharge was achieved by an auxiliary multiple spark discharge formed between a trigger electrode and one of the main discharge electrodes. In operation, breakdown of the gas between the mesh and the trigger electrode occurred first and resulted in the formation of many small arcs. High speed photographic studies indicated that uv radiation emitted by these arcs produced volume photo-ionization

throughout the entire laser gas mixture. This provided a much greater stabilizing effect on the main discharge than photo-emission from one of the electrodes, a process which had been used in several other laboratories.

With a view to the development of a large volume $CO_2$ amplifier, capable of storing energies of about 100 joules, seven identical modules were assembled during the winter of 1971/72, with the discharge cross-section increased to 58 $cm^2$. When seven modules were operated together as a large oscillator, a total output energy of 300 J at an overall efficiency of $\sim$8% was obtained. The peak power of the device exceeded 3 gigawatts and demonstrated for the first time that high power $CO_2$ laser systems could be constructed without resorting to the more costly electron-beam sustainer approach.

Additional scaling studies were carried out during the summer of 1972, in which the uv source and the main discharge were energized independently, thus permitting the development of the "flashboard," a much more effective, large area uv source. Although no full-scale laser module was constructed the results revealed that the electrode separation could be increased up to $\sim$30 cm and confirmed that the construction of $CO_2$ lasers with apertures as large as 600 $cm^2$ did not present any major obstacle. This result rapidly led to the awarding of a development contract to Lumonics Research Ltd. who have now built and sold approximately ten 20 cm aperture $CO_2$ discharge modules. In addition the "flashboard" uv

radiation sources are now being used in other commercial lasers (Lumonics 600) and have found their way into many laboratories around the world. So far, the principal applications of these high power $CO_2$ lasers have been in research laboratories; however there is a good probability that industrial applications will evolve in the years ahead.

Additional experiments carried out at NRC have resulted in the successful operation of a small uv pre-ionized laser at a gas mixture pressure of 15 atmospheres. This development has extended the capabilities of the $CO_2$ laser even further since multi-atmosphere operation permits the generation of ultra-short pulses and allows the output frequency of the laser to be tuned continuously within a narrow band of wavelengths. This property makes the laser particularly useful for research in spectroscopy and photochemistry and it is expected that a commercial product based on this device will be developed.

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## OPTICAL MULTILAYER COATINGS FOR ANTI-COUNTERFEITING PURPOSES

In 1971 the Bank of Canada approached NRC with a request for suggestions of new ways to inhibit the counterfeiting of paper currency. Several proposals were made at that time, including, for example, the magnetic encoding of banknotes. The Optical Physics Section of the Division of Physics looked into the use of metameric colours, but found a more promising approach based on its ongoing research

program on the properties, design and construction of optical multilayer coatings. This work led to the development of a method that can offer protection to the citizen from small and medium sized counterfeiting operations.

Optical multilayer coatings usually consist of a substrate, which may be made of glass or plastic, onto which a number of thin films of different materials have been deposited. These materials may be elements, such as silver, gold or aluminium, or simple inorganic compounds, such as zinc sulphide, magnesium fluoride or zirconium dioxide. A commonly used method for the deposition of the layers is thermal evaporation in a vacuum. The thicknesses of the individual films are of the order of the wavelength of light, and they have to be controlled with a very high precision. Some multilayers may consist of as many as 50 or 60 different individual layers. The reflection or transmission of light by a multilayer coating depends on the number of constituent layers, their thicknesses and optical constants. The colour effects observed are due to the inference of light in thin films; the same principle that is responsible for the colours of soap bubbles and oil slicks. But because in the multilayer coatings many more films are involved, and because their thicknesses and optical constants can be controlled, it is possible to obtain almost any desired transmission or reflection characteristics.

With the NRC device, special optical multilayer coatings are made an integral part of the article to be protected from counterfeiting. Coatings have been developed at the NRC which change colour, or which reveal hidden designs when viewed obliquely. These effects cannot be duplicated by any known dye, ink, photographic or xerographic process. They should therefore enable anybody to distinguish at a glance an authentic article bearing such a coating from even the best counterfeit lacking it. The security of the device lies in the fact that the coatings can be produced only by the use of sophisticated and expensive equipment, and that their cost is prohibitive for most applications when made in small quantities. Patent protection for this idea has been obtained in Canada and several foreign countries.

Identicard Ltd., a Toronto-based Canadian company producing identification cards, learned about the NRC method from publicity in connection with a talk at a scientific conference. It carried out a market survey in 1973 on possible applications of the coatings and found that the coatings could also be used for the protection of identification cards, drivers' licences, passports, credit cards, cheques, share certificates and airline and lottery tickets. There exists a very considerable export potential for this product.

In view of these prospects Identicard Ltd. approached Canadian Patents and Development Ltd. and leased from them rights to this invention.

The mass production of such complex coatings, necessary both to supply the huge quantities needed and to bring down their cost, has never been attempted before. With the help of technical staff placed by Identicard Ltd. in its laboratories, the NRC had to do a considerable amount of development work to reach the present situation where the construction of a prototype production machine can be contemplated. It is expected that this prototype will be designed and built for the NRC by Sentrol Systems Limited, of Toronto, with the collaboration of the Canadian Vacuum Equipment Co. Ltd. of Montreal, and the Lembo Corporation of Canada, Midland. NRC will assist these companies to establish themselves in this new high technology industrial field. The construction of the prototype will be funded through the PILP grant program and should take about 14 months. After the conclusion of the tests on the prototypes, Identicard Ltd. will finance the construction of a full-scale production machine.

The techniques and equipment developed for this project will give Canadian industry a head start in the development of a range of new products, such as high-quality, low-cost optical coating and filters for scientific, technological, and commercial applications; improved and cheaper architectural coatings for energy conservation purposes; and coatings for solar-energy conversion.

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EXTRACTION OF BITUMEN FROM ATHABASCA TAR SANDS

National requirements for the production of synthetic crude oil from the Athabasca Tar Sands have been predicted to be about one million barrels a day within 10-20 years. At the present time the only technology available to exploit this immense national resource is the Hot Water Process currently used by Great Canadian Oil Sands (G.C.O.S.) in the only operational commercial plant. An important parameter in the operation of a Hot Water extraction plant is the amount of fines present in the feed material. The fines are defined as that mineral matter that will pass through a 325 mesh (44 microns) screen; this fraction may be further sub-divided into silt and clay components. The major problem encountered in the operation of Hot Water extraction plants is that the fines content of the deposit is often significantly higher than the expected value of 6-10%. This has caused major technical difficulties at the G.C.O.S. plant.

Hot Water extraction plants require huge quantities of water and there is a corresponding production of liquid effluent. The effluent is discharged at a temperature of 70°C and pH 9.3; it is also heavily contaminated with oil and cannot be discharded into natural waterways. The fines in the effluent remain as a stable aqueous suspension of clay and oil. This suspension cannot be completely recycled back to the process, because the suspended clay would further reduce the bitumen extraction efficiency in the primary stages.

There is, therefore, an overall accumulation of effluent. The current solution to this problem is to establish huge retaining ponds; these ponds will represent a continuing threat to the environment through seepage into natural groundwater and effects on local climatic conditions. These problems have been outlined in environmental studies carried out for the Alberta government.

The Colloid Section of the Division of Chemistry has had considerable experience in the field of fine particle technology and has also been involved in tar sands extraction projects. As a result of this experience, the Colloid Section was one of the groups approached by industrial and government representatives, to seek a solution to the problems currently being encountered by industry. Two approaches to the solution of the problems were adopted; first the treatment of the effluent to reduce the clay content, allowing greater recycle of the water and secondly the development of alternative bitumen extraction techniques, which would avoid or reduce the effect of high fines component in the feed. Of these approaches the second has received the most industrial interest.

Solvent extraction of the bitumen is one alternative to Hot Water treatment that has been extensively studied because its effectiveness is largely independent of fines content. Even in the Hot Water process, solvent extraction is used as a final recovery step. Another advantage of an anhydrous solvent extraction process is that the effluent is

a readily disposable solid. However, the problem with this technique has always been an unacceptably high retention of solvent in the sand tailings.

A process known as "Spherical Agglomeration" was developed in the Colloid Section a number of years ago, and is now beginning to achieve industrial acceptance. In this process a suspension of fine particles is agitated with a second liquid which preferentially displaces the suspending medium from the surfaces of the particles. Under suitable conditions the result is compaction of the fine particles into larger, spherical pellets, which are readily separated from the suspending liquid. By optimising the volume of second liquid needed to form the pellets it is possible to exclude most of the suspending medium from the internal pore volume. As applied to bitumen extraction from tar sands the process involves suspension of the sand in a suitable bitumen solvent, followed by further agitation in the presence of sufficient water to form the sand pellets. The bitumen remains dissolved in the suspending liquid and is separated from the sand pellets by a simple settling procedure. The pellets consist of sand and water with some residual solvent. The solvent is removed from the bitumen solution by distillation and recycled. Make-up solvent, to replace losses, is taken from the products of bitumen "cracking".

In order to combine the "Spherical Agglomeration" process with the solvent extraction of bitumen on a continuous

basis, it was necessary to develop a novel apparatus. This apparatus consists of a conical, rotating drum, so designed that counter-current solvent extraction of the bitumen and sand agglomeration occur simultaneously. The shape of the drum is such that the sand pellets are ejected at one end and the solvent-bitumen solution at the other.

The process has been licensed by a Canadian company, through Canadian Patents and Development Limited. At the moment the Colloid Section is collaborating with the licensee in the design of a larger laboratory unit, which will include all the prerequisites of a full-scale pilot plant. This unit will be operated to develop control parameters for the process and to determine its economic viability. If this program proves successful, funds from the private sector of industry will be available for the construction and operation of a commercial-size pilot plant. The development of the NRC process to commercial fruition will allow a more efficient extraction of bitumen from the Athabasca Tar Sands, while minimising the ecological damage threatened by the present industrial proposals.

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## AN ENERGY-CONSERVING RAILWAY SWITCH PROTECTOR

Informal discussions with railway people are a long established custom of the National Research Council Laboratories, and the substance of some of these discussions has been codified by the NRC Associate Committee on Railway Problems. Major Canadian railways asked for the assistance of the Sub-Committee on Climatic Problems on the question of railway track switches failing as a result of snow and ice deposits.

The classical approach to the problem had been to provide heat; however, the combustion heaters that both major railways had installed during the 1960s were designed outside of Canada for much milder climates and had proven inadequate for many areas of Canada.

A multiple approach technique was employed on this problem. Initially environmental conditions were established for design and test standards that would be representative of natural conditions and capable of being simulated in an environmental chamber. Existing heaters were laboratory tested, eliminating those completely inadequate and, in cooperation with suppliers, upgrading and improving some marginal equipment.

While the above program was underway, a second phase was initiated to develop a suitable combustion heater for remote areas where insufficient electrical power existed to operate conventional combustion heaters. A pulse jet powered switch heater was developed, fuelled by propane and capable of operating from signal power.

A third phase was started when it was recognized that thermal protection would have to be considered an interim solution to the problem. The ideal solution is a new switch that is not subject to failure from ice and snow. A switch was designed that, in transferring with snow or ice present, subjects the foreign matter only to shear loading, in contrast to compression loading in existing switches. Design, development, and evaluation work on this concept are continuing and two switches have been made and field tested. It is considered as a long term (15 to 20 years) solution to the problem in view of the existing capital investment in point switches.

While conducting research and development programs to improve the performance of combustion heaters for switches and to provide alternate heaters for remote areas, consideration was given to other possible solutions to this problem. A new method of dealing with the snow problem of railway switches resulted from observations on another unrelated project.

One of the long range projects of the Low Temperature Laboratory is the study of snow removal from the tracks of high-speed, guided, ground transportation systems. One of the methods of snow removal under investigation is the use of high velocity air jets. During this test program, it was noted that once the snow was removed from the surface, the air jet could move the snow a considerable horizontal distance. A review of the literature relating to the terminal velocity of snow particles and the horizontal transport of snow as measured in

blowing and drifting conditions indicated that an air jet system forming a protective horizontal air curtain might be feasible, thus preventing falling snow from depositing in selected areas.

The terminal velocity of snow particles ranges from values less than 0.3 m/sec. to approximately 2.0 m/sec. depending upon the shape, size and density of the particle. The horizontal transportation of airborne snow is a power function of the wind speed and, typically, a horizontal mass flux of 1000 $g/m^2$-sec. can be attained at velocities over 25 m/sec. The vertical mass flux is usually expressed in terms of the snowfall accumulation rate. Given the snowfall rate, the mean density of freshly fallen snow and the particle terminal velocity, an airborne vertical mass flux can be calculated. Snowfall rates vary widely, but in Canada the greatest snowfall in one day was 43 inches at Premier, B.C. on January 15, 1949. Thus, a design figure of two inches snowfall per hour should be acceptable.

From this data, calculations can be made of the theoretical air mass flow to protect a horizontal surface from snow deposition. There are other considerations that must be taken into account and in the specific case of protecting a track switch from snow deposit, these include the configuration of the switch, the clearance outline within which equipment can be mounted, critical switch areas, and allowable snow deposit areas. Another factor to consider is that a jet of air expanding freely in the atmosphere experiences a velocity

decay as a function of distance from the nozzle. This velocity decay precludes moving snow great distances horizontally by a single jet.

The question of configuration of a practical system to protect a switch was further complicated by the necessity to design for high wind velocities, up to 40 mph, having directions either in counter flow or crossflow to a protective air curtain. Initial experimental work and some of the practical limitations resolved the design to two outward directed jets moving the snow from within the area between the stock rails to outside of track. The clearance outline limited the height of the jet outlet to approximately rail head height. It, therefore, was necessary to give the jet a vertical component in order that the expanding air jet would clear the stock rail head and permit snow deposition in the selected areas. The outlet velocity of the jet was dictated by the considerations of mean velocity for snow transportation, velocity decay and counter flow velocity. The mass flow of the jet was dictated by the required horizontal mass flux of snow.

Following some small scale experimental work in the late winter of 1971-72, a prototype system was designed and fabricated during the spring and summer of 1972. It was tested initially in a large cold chamber under simulated conditions, and in the late fall of 1972 the prototype system was installed on an isolated inactive switch at an Ottawa test site. The horizontal air curtain switch protector consists of a centrifugal fan with

a low velocity inlet, a discharge duct crossing below rail level and between a pair of ties to connecting elbows. From each elbow, a longitudinal duct extends horizontally and parallel to the adjacent stock rail. A full length slit nozzle extends along the outside of each duct.

The horizontal air curtain requires a 5 KW electrical input to protect switches up to 22 feet long. Forced convection combustion heaters for switch protection require approximately one KW electrical input and a fuel supply equivalent to 250,000 BTU per hour. To compare the two systems on a more rational basis, the air curtain system would require approximately 60 to 70,000 BTU per hour in fossil fuel input to an electrical generating plant, allowing for plant and distribution losses. Thus for equivalent operating times, the horizontal air curtain could reduce the energy consumption by about 75 percent. Following a year of trials at the Ottawa site, the prototype was moved to Montreal and installed in the classification yard of the Canadian National Railways. After a second season of tests without a failure on either the inactive or the active switch, a decision was made to modify the design for possible production.

The second unit was produced to meet the revised design requirements. Numerous detailed changes were made to simplify component fabrication and assembly although the performance requirements were maintained. This second prototype was installed on a parallel switch in the CNR Montreal classification yard during the winter of 1974-75.

To date the original prototype has been exposed to a total of 267 inches snowfall over the past three winters without experiencing a failure. The average snowfall rate was 0.2 inches per hour. The highest average rate encountered during one storm was 1.35 inches per hour. The maximum snowfall accumulated during a climatological day was 10.5 inches.

Patents have been applied for on this switch protection system in a number of countries. Arrangements have been made to manufacture this equipment in Canada, under license from Canadian Patents and Development Limited. There are naturally a number of developments of these ideas already in view.

CNR has purchased a number of units from the licensed Canadian manufacturer to conduct a wide scale evaluation program extending from British Columbia to Nova Scotia.

It is anticipated that the existing design horizontal air curtain system powered by a three phase electrical supply will gradually be adopted for all switch protection in yards and terminals in view of the fuel saving to be realized. For main line switches where three phase power cannot be supplied readily, either single phase electrical or a diesel engine driven system may be required. These will require development by the laboratory and the manufacturer. Discussions are now being held on possible means of arranging for this development work in industry.

For the railways, ultimate economic benefits should be reduced costs of winter railway transportation in terms

of lower capital cost for equipment and lower operating cost with greater reliability. The manufacture of this system in Canada will eliminate the importation of some thermal protection equipment. The successful development and marketing of the air curtain switch protector should lead to an annual export volume in the $10,000,000 range.

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## BIOMEDICAL ENGINEERING

The Division of Electrical Engineering continues a 25-year involvement in cardiovascular investigations of diagnostic and therapeutic procedures. Projects are being conducted on ultrasonic diagnosis, cardiovascular research and development and instrumentation for patient treatment and diagnosis.

### The Echo-Encephalograph

The development of a compact hand-held echo-encephalograph stemmed from an early ultrasonic study conducted in collaboration with Queen's University. A need was recognized for a portable instrument which could assess brain damage by detecting a shift of the midline ventricular structure of the skull. A potential application was visualized in assessment of damage incurred in accidents and the device was designed for possible use in ambulances in addition to clinical measurements.

The echo-encephalograph was developed over the period of 1970-1973. It was assessed at the renowned Basle Neuro-logical Clinic where it was compared with the EMI brain scanner, a very complex x-ray system that employs a dedicated

computer for cerebral investigations. These tests showed the validity and high accuracy of the NRC instrument and it was exposed to clinical use in hospitals at Montreal, Kingston and Winnipeg. A patent was granted in 1973 and manufacturing rights were awarded to Radionics Ltd. Montreal. Picker International has acquired the U.S. marketing rights and approximately 80 units had been sold by November 1975. The echo-encephalograph has proven comparable in diagnostic capability with other more complex equipment, some of which is beyond the economic reach of many hospitals. The development was reported at three international medical conferences and evoked great interest.

Subsequently, a histogram plotter has been developed as an ancillary readout device. This has now reached the stage of commercial application and Radionics Ltd. has expressed interest in its manufacture. NRC continues to assist the manufacturer.

Cardiac Parameters in Pacer Studies

The Division of Electrical Engineering has been involved in cardiac stimulation since it provided the first cardiac pacemaker for a pioneer hypothermia study at the Banting Institute in 1949. The NRC contribution was recognized in 1975 on the occasion of the opening of Canada's first pacemaker plant by Medtronics Inc. In the period 1967 to 1974 the NRC group concentrated on biological energy sources to ensure longer dependable service by implanted pacers.

The study of cardiac parameters arose from these earlier investigations. It commenced in 1967 and was completed in 1974. The objective was to optimize stimulating parameters (pulse width and wave form) to conserve battery energy, extend pacer life and reduce cellular damage to cardiac tissue.

Overlapping the latter part of this investigation were studies of the thresholds of ventricular arrhythmia and disruption of contraction, and of the onset of ventricular fibrillation. They were initiated in order to resolve a controversy in the determination of appropriate levels of protection to be specified in Canadian hospital safety standards, in which the Division has a leading commitment.

In parallel with these investigative studies, the group collaborated with Atomic Energy of Canada Limited in the evaluation of nuclear pacers. In this study, AECL provided the energy sources and NRC designed and packaged the implantable pacers. The study is still in progress.

In cardiovascular research and development, the Division is established as a major centre. The studies of cardiac parameters have been applied in a program at Drexel University in the U.S.A., and the technology which it produced has been used in pacemaker design by Pacers Ltd. in Britain and Seimens Ltd. in West Germany. An extensive review of cardiac pacemaker technology was published in Critical Reviews of Bioengineering, in 1975 by a member of the Division.

The investigations of cardiac parameters have provided new data on the thresholds of cardiac disruption leading to

the irreversible state of ventricular fibrillation. The research has influenced the determination of levels of protection in national and international medical safety standards, revealing a much more critical situation in the application of modern catheterization techniques and revising old concepts of the nature of induction of ventricular fibrillation. An important result of the research may be a new clinical technique for mapping areas of cardiac infarction (tissue destruction).

An estimated 140,000 cardiac patients are maintained by implanted pacemakers based upon the NRC development.

Cardiac Tachometer

In 1972 a cardiologist suggested to the Division of Electrical Engineering that there was a need for an inexpensive, easily-applied heat rate meter for use during or following surgery, or for monitoring heart patients during exercise.

A pulse recurrence frequency direct-reading device was developed and licenced by 1974. It provided two modes of operation: from the blood pressure pulse in a finger or from an incorporated electrocardiograph amplifier and chest lead electrodes. The pulse detection technique was designed for anaesthetized patients where motion artifacts were not a problem. It utilized a simple and inexpensive transducer. Both devices performed well during clinical tests at the National Defence Medical Centre. The tachometer was completely engineered at NRC. The methods used for scale linearization

in the design of the cardiac tachometer are new and so much simpler that they are being used by other researchers. Five prototypes were built to eliminate anticipated problems in commercial production. The licencee, Harco Development Co., Winnipeg obtained a $5000 grant from the Manitoba Development Corporation for design of a diecast plastic package, printed circuitry and assembly layout. The resulting instrument has been successful on both domestic and export markets. In the past one and one half years, the company has sold 140 units at an average price of $300, generating a cash flow of approximately $40,000.

The tachometer was designed from the outset with commercial manufacture in mind. In order to be competitive and inexpensive, reliable components were used, including the adaptation of a transistor radio earpiece as a pulse transducer. The circuitry was simplified in comparison with other heart-rate meters on the market. It permitted the measurement of both instantaneous and average heart rates. In addition the current drain from the batteries was so low that the unit could operate for extended periods of time without failure. This is a significant design feature for Intensive Care Units and long surgical procedures. Existing tachometers function for only three or four hours of continuous service. The NRC unit, with easily available transistor radio batteries, can operate continuously for five days.

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## WIND POWER

The National Research Council has been designated, by the government's Energy R&D Task Force, as the lead research agency in the task of exploiting renewable energy resources. Wind energy is one of these resources, and it is presently being studied closely in many countries, including Canada. Unfortunately, its potential remains uncertain: estimates of its impact range from a small fraction of one percent of national electricity needs in the next 20 or 30 years, to as much as 10 percent or more.

The uncertainty is not one of resource supply, at least in countries with large geographical areas. In the U.S. it has been estimated that wind energy, if farmed over only the western plains states, could give four times the present national electricity consumption. Equally impressive statistics apply to Canada: for instance, there is much more wind power available within the drainage basin of the La Grande River in Quebec (James Bay Project) than the planned capacity of the massive hydro project now under construction there.

There are other attractions to the exploitation of wind energy. It is one of the most environmentally benign energy sources; the La Grande basin calculation just mentioned was based upon a wind turbine spacing so wide that even the wind environment itself would be essentially unaltered by the energy extraction. It can also be shown that the energy

invested in materials and manufacture of large wind plants can be returned within the first few months of operation - a net energy return period shorter than that of, say, nuclear plants.

However, many real problems must be faced before wind power systems can be brought into large scale use. At present the capital cost is too high to compete with most other forms of energy, especially in the highly populated parts of Canada where we have become used to cheap electricity. The productivity of a wind plant is highly sensitive to its location; in Canada high average winds are available on the east coast, in large areas around Hudson Bay and in the southern prairies. Most Canadians live elsewhere. At any given location, the wind is intermittent and often rather seasonal, so problems of energy storage have to be considered in some applications. There is also an environmental uncertainty. People are distressed by the unsightliness of large arrays of transmission towers; how would they feel if the towers had rotating blades? Power companies, at least in their operational branches if not in their research departments, remain to be convinced that wind energy can be mixed with their systems to provide reliable power on demand.

In spite of these deterrents to development, there are good reasons for sustaining a small, but vigorous wind energy program in Canada. One is to "keep our options open" in the face of an uncertain energy future, but of course this

can be applied to all R&D activities. There are other reasons. Five of Canada's ten provinces have coastal and island regions in and around the Gulf of St. Lawrence, one of the windiest parts of the country. Present energy costs are high in parts of these provinces, and likely to go on rising as the price of fossil fuels increases. Wind energy could be applied with local benefits today, and several provincial power authorities are examining its feasibility. Large and small wind turbines have many applications in more remote locations, where experimental plants are already operating. Most available windmills are small, expensive, and must be imported, although the required technology is well within the capability of Canadian industry. If even one-tenth of one percent of presently installed generating capacity in Canada were to be replaced by wind power, the wind plants would represent about $50 million worth of business within Canada alone. One significant technological development has already resulted from Canadian research, first in government, and subsequently in industry. The vertical axis "egg-beater" turbine was an old "lost" invention, independently re-invented in the mid-1960's by Peter South and Raj Rangi at NRC, when consideration was being given to intermediate technology devices that might be appropriate to remote underdeveloped areas. Although initial small-scale wind tunnel investigations gave encouraging results, the project was maintained at a low level of activity. In the

early 1970's, just before the energy crisis struck the industrialized nations, the first large scale test was carried out in the new 30 ft. wind tunnel, and results were published. World-wide interest became intense and has remained so to the present time. A computerized aerodynamic performance theory suitable for design optimization has been developed, and aeroelastic model experiments and analysis have uncovered no obstacles to the construction of very large turbines of megawatt capacity.

The vertical-axis turbine has several advantages over other more conventional windmills. The most important of these is potential cost reduction due partly to its simple, light-weight structure. Power take-off is conveniently near ground level. There is no "tower" of the usual kind, and operation is independent of wind direction. Its aerodynamic characteristics make possible direct coupling, through commercially available synchronous or induction generators, to existing alternating current grids. In this service, the turbine automatically "unloads" in very high winds, so that no feed-back control system is required either for control in normal operation, or for the equivalent of blade feathering in large horizontal-axis propeller type windmills.

Small versions, rated at up to six kilowatts, have been developed with NRC assistance, to the production prototype stage by three Canadian manufacturers. One of these companies is now designing and building, under NRC sponsorship,

a large machine (150 ft. high) for direct coupling to the existing diesel-powered grid system in the Magdalen Islands in late 1976, where subsequent trials will be conducted by Hydro Quebec with the cooperation of NRC. The purpose of this project is to demonstrate the feasibility of this new type of power-generating wind turbine in a realistic application, under severe environmental conditions.

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## DEVELOPMENT OF LEGUME SEEDS

The Prairie Regional Laboratory was opened in 1948 to develop research programs directed to the industrial utilization of agricultural surpluses (e.g. wheat) and wastes (e.g. cereal straws). The production of alternative crops was selected as an effective means of reducing surplus production. The selection of an alternate crop is based on three criteria: potential for economically competitive production, a domestic market, and potential for an export market. The first crop selected for R&D, rapeseed, fulfilled the three criteria. The program, which eventually involved other government departments, universities, and industries produced the "Cinderella" crop ranging from 3.5 to 5.0 million acres per year since 1971, several new industrial plants, a major export commodity and a gross productivity of 200-500 million dollars annually.

An evaluation of the program around 1961 indicated that rapeseed was replacing imported soybeans in fulfilling the requirement for a domestic vegetable oil. Since rapeseed had twice the oil content of soybean this effectively reduced the amount of protein in the form of domestically processed oilseed meal for the livestock industry thereby creating a domestic demand for another source of protein supplement. Consideration was given to three potential protein sources single cell proteins (SCP), leaf proteins such as alfalfa, and legume seed proteins. The legume seed proteins were given top priority and field peas were selected in 1967 for a new R&D program replacing the rapeseed research transferred to other organizations. Field peas had been successfully grown in Canada on a limited acreage, primarily for the soup trade, and there was a potential for an expanded export market based on world predictions of an increasing demand for protein by a growing population with an increasing standard of living. The field peas and legume seeds had higher protein contents (24%-30%) than the cereals (10-15%), and could be expected to replace soybeans (also a legume seed) both as a livestock feed and for human food products. The only research in Canada on peas was a limited plant breeding effort on varieties for canning and the soup trades, where protein content was not a factor.

The initial research provided basic information on production and utilization. A survey of the protein

variability in the world collection, conducted in collaboration with Agriculture Canada, and a limited selection program showed that the protein content of Canadian varieties could be increased by plant breeding and selection. This project was transferred in 1971 to the Crop Development Centre of the University of Saskatchewan which was created under a negotiated development grant by the National Research Council. Nutritional evaluations in collaboration with the Animal Science Department of the University of Saskatchewan established the quality of the protein. Since protein was the key factor, dry milling and air classification were established as the preferred processes both technically and economically. The purchase of laboratory-scale industrial equipment established a facility to produce quantities of protein and starch for utilization studies. Samples of protein and starch were provided to interested feed and food industries for evaluation in market products. The positive responses led to feasibility studies for a primary processing plant by Canadian industries. A pilot plant constructed in 1972 by Newfield Seeds operated on contract acreage and produced protein and starch in sufficient quantities for plant scale tests by feed and food industries. The positive results led to the construction of a full scale (50 tons/day) commercial plant. The same company licensed patents developed at the laboratory for snack foods and meat extenders and are

conducting the necessary development research under the Industrial Research Assistance Program of the National Research Council.

The present program on production and utilization of legume seeds is being expanded with emphasis on two key areas. The starch yield from legume seeds is twice the protein yield, and consequently, expanded utilization depends on the development of markets for this by-product. No research was being conducted in this area by any other Canadian research group.

A research program on "nitrogen fixation", the ability of legumes and soil microorganisms to convert atmospheric nitrogen into ammonia for protein synthesis, was initiated in 1967. This program is directed particularly to field peas and the major advances that have been made are being tested in practical plant selection programs. The effects on commercial chemical fertilizers of rising costs and availability of energy have recently made research on nitrogen fixation a high priority in countries concerned with agricultural production. Canadian interest is concerned with improving the economics of legume production by reducing the fertilizer requirements and optimizing crop and protein yields.

The present production of field peas (excluding the soup and canning trades) of 12,000 acres is valued at around 1.5 million dollars a year, with a similar value for fababeans.

The field pea acreage will double in the next crop year with construction of the commercial plant. The target figure for Canadian production of legume seeds is one million acres which would place the industry in the 100-150 million dollar a year category and provide the farmer with another crop, create additional industries, and give Canada a protein source presently only available through imported soybeans.

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## DEVELOPMENT PROJECTS OF THE CANADA INSTITUTE FOR SCIENTIFIC AND TECHNICAL INFORMATION

### Canadian Selective Dissemination of Information (CAN/SDI) Service

The initial work on the computer-based current awareness service commenced in 1966. It scanned the citations of scientific and engineering papers published in selected journals, and provided NRC scientists and engineers with bibliographies of papers in their specific fields at regular intervals. The initial experiment was based on the Chemical Titles data base, one of the first indices to be made available commercially in machine readable form. After a development period (1967/69) of serving NRC personnel, the service was made available nationally on a subscription basis in 1969, with two data bases. Subsequently, the service grew rapidly until now there are 15 data bases and 2,091 subscriptions serving over 6,000 engineers and scientists across Canada. The service is supported by some 500 NRC-trained search editors in government, industry, and the universities. This service is probably the best known of its type in the world, having been made available internationally through UNISIST. NRC has provided the software and expert assistance in the establishment of the system in Australia, the United Kingdom, South Africa, Argentina, India, and Mexico.

### Information Exchange Centre for Federally-Supported University Research

In July 1970, NRC was directed by the Cabinet to establish

an information exchange centre to cover all federally-supported university research in all of the sciences. A 19-member task force representing the main granting and user agencies was convened to identify objectives and outline methodology. In early 1971, a small working unit was formed. It designed a data input form and began negotiating with 22 federal agencies regarding who is doing what research where and how it is supported. In May 1972, the first annual data base for IEC was completed containing 10,363 ongoing research projects in the 1971/72 fiscal year. A year later, the first 2-volume IEC Directory was printed and offered for sale at $50.00. All 350 copies were sold in less than four months. This Directory has become a regular annual publication of the Canada Institute for Scientific and Technical Information, and a standard reference tool for Canadian libraries, government agencies, and research institutions. The latest edition covering fiscal year 1974/75, contains 9,425 current research projects as reported by 29 federal granting agencies.

Canadian On-Line Enquiry (CAN/OLE) Service

This is a computer-based, interactive system for the retrospective searching of large bibliographic files. It is based on a general-purpose data base management system being developed by NRC for such purposes. The work commenced in 1972, and in 1973 the system was used on an experimental basis by the Reference Section of CISTI. In July 1974 the CAN/OLE Service was commenced on an experimental cooperative

basis by 15 centres in federal and provincial agencies, universities, and industry. Each centre contributed a monthly subscription fee plus additional charges for use over a threshold level. On April 1, 1975 the service was placed on a fee-for-service basis and additional applications were accepted from organizations that desired to use the service. A target of 40 centres was set for fiscal year 1975/76. Four of the world's largest data bases are available for searching, covering the following subdivisions of the world's scientific and technical literature: chemistry; physics, electro-technology, computing and automatic control; the life sciences; and engineering. In addition, the Union List of Scientific Serials in Canadian Libraries can be searched for the location of libraries holding the publications, once the references of interest have been identified. Though still under development, the system has been compared favourably with the two largest American services by studies done at the University of Calgary, but the number of data bases is not as extensive as those available on the American systems.

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